*__Original Research Article__*

**Effect of pre-colored zirconia copings on the final color of zirconia veneered restorations**


**Abstract**

*Background:* This study aimed to investigate the effect of different zirconia coping shades on the color and translucency of zirconia-based restorations.

*Material and Methods:* Zirconia core plates were fabricated from the non-shaded and pre-shaded translucent zirconia materials and were divided into four groups (n=11) according to their shade: Bleach (B), A2, A3, and A4. Next, they underwent porcelain veneering and glazed. The CIELab color measurements were performed before and after porcelain veneering by a colorimeter against white and black backgrounds. Color difference (ΔE) between the groups and translucency parameter (TP) were calculated. ΔE values were compared with perceptibility (ΔE=2.6) and acceptability (ΔE=5.5) thresholds. Data were analyzed by paired t-test, one-way analysis of variance, and Tukey's Honest Significant Difference post hoc tests ($P < 0.05$).

*Results:* The TP and ΔE of the samples significantly decreased in all groups after porcelain veneering compared with baseline ($P<0.001$). Against a black background, the ΔE of all groups was below the perceptible threshold after porcelain application ($P<0.001$). Against a white background, ΔE of all groups decreased to a level lower than the perceptible threshold after porcelain veneering except for groups B-A3 (ΔE=3.02±0.73) and B-A4 (ΔE=4.10±0.70), in which ΔE was between the perceptible and acceptable thresholds ($P<0.001$).

*Conclusions:* Porcelain veneering reduces ΔE between two samples more efficiently than pre-colored zirconia copings, especially against a dark background.



**KEYWORDS**

Ceramics; Color; Colorimetry; Zirconium Oxide


## 1. Introduction

Dentistry is to achieve natural-looking restorations, and the shade matching of the restorations with the natural dentition is a difficult challenge(Vichi et al., 2011). Recent ceramic materials mimic the optical properties of teeth very naturally, and their mechanical characteristics have been significantly improved to provide good longevity and predictability(Zarone et al., 2011).All-ceramic restorations can be used as bi-layered or full-contour restorations. In the bi-layered, the ceramic core supports the restoration and gives it strength, and the veneer provides the restoration with its final shape, shade, and aesthetic. The core may also play a part in developing the final restoration's shade(Warreth & Elkareimi, 2020).

Zirconium oxide is currently the most widely used coping material due to its high flexural strength and fracture resistance. However, its white and opaque appearance does not meet esthetic requirements(Choi & Razzoog, 2013).As a result, manufacturers have presented pre-colored zirconia ceramics, color liquids, and liners to improve the color of porcelain-veneered zirconia restorations(Tabatabaian, 2019). Pre-colored zirconia ceramics are produced by various techniques, such as a heterogeneous nucleation method and mixing metal oxides such as $Fe_2O_3$, $CeO_2$, and $Bi_2O_3$ to zirconia powder(Kaya, 2013; Tabatabaian, 2019; Wang et al., 2012). Aside from the possible effects of metal oxides/salts on zirconia properties such as density and flexural strength, these additives significantly impact the CIELab values of the ceramic(Jiang et al., 2015; Shah et al., 2008). Several shades of pre-colored zirconia blocks are available in the market, and most color groups were denoted by the name of VITA classical shade tabs(Tabatabaian, 2019).With the development of pre-colored zirconia blanks, evaluating the effect of various pre-colored zirconia copings on the translucency and color of porcelain-veneered zirconia restorations is helpful. Although the masking ability of zirconia and the effect of core/porcelain thickness on the final color of restorations have been previously investigated(Dikicier et al., 2014; Fathi et al., 2019; Tabatabaian, Jafari, et al., 2019),information regarding the optical properties of porcelain-veneered zirconia restorations with pre-colored zirconia copings is limited. Therefore, the present *in vitro* study aimed to assess the effect of different zirconia core shades on the color and translucency of porcelain-veneered zirconia restorations. The null hypothesis was that there would be no differences in the TP and ΔE of a 1.5-mm-thick layer of ceramic fired on different pre-colored zirconia substructures.

## 2. Materials and methods

The translucent zirconia disk and blocks used for the coping and the veneering ceramics are specified in Table 1.

A total of 44 square-shaped zirconia specimens (12mm×12mm with 0.5mm thickness) were milled from inCoris TZI C blocks (Dentsply Sirona, Germany) and inCoris TZI zirconia disk (Dentsply Sirona, Germany) using computer-aided design and computer-aided manufacturing (CAD/CAM) (CORiTEC 250i; imes-icore, GmbH, Germany), and the milled zirconia cores were then sintered in a high-temperature furnace (in Fire HTC speed - Dentsply Sirona; Germany) according to the manufacturer's instructions. Samples were then adjusted to achieve the intended thickness of 0.54±0.04 mm using a zirconia polishing kit (BruxZir, Glidewell Direct, Irvine, CA, USA). A digital caliper measured all specimens' thickness (INSIZE 1108-150). The zirconia sample was eliminated from the study in case of unacceptable thickness. Final zirconia specimens were cleaned with a digital ultrasonic cleaner (Vevor Commercial Ultrasonic Cleaner, 3L, Vevor, Canada) containing 96% ethanol for 15min and air-dried. Next, the specimens were divided into four groups of 11 samples according to the classical colors of A2, A3, and A4, and the bleach shade (B) served as the control group. The CIE color coordinates L*, a*, and b* of zirconia samples was measured by a colorimeter (Chroma Meter CR-400, Konica Minolta, Sensing, Singapore) over a white (L*=92.09, a*=1.15, b*=-4.8) and a black (L*=15.55, a*=2, b*=0.95) background relative to the manufacturer's instructions. A putty silicone material (Speedex; Coltene, Altstatten, Switzerland) was formed around the tip of the colorimeter to standardize the position of specimens relative to the background and the tip of the colorimeter and to prevent external lights. Triplet measurements were performed by an expert operator at the center of each specimen, and average readings were used for data calculation. Before each experimental measurement, the colorimeter was calibrated to a standard white tile in the kit. The translucency parameter (TP) and the ΔE were evaluated. TP was estimated by the difference between color coordinates measured using the following equation:

$$TP= [(L_W^* - L_B^*)^2 + (a_W^* - a_B^*)^2 + (b_W^* - b_B^*)^2]^{1/2}$$

Subscript B corresponds to the color coordinates over the black background, and subscript W corresponds to those over the white background. The greater the TP value, the higher the translucency of the material.

The ΔE* between the groups against the same background was calculated as per the CIE76 formula:

$$\Delta E^*= [(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2]^{1/2}$$

Perceptibility (ΔE*=2.6) and acceptability (ΔE*=5.5) thresholds were assumed to interpret the color differences(Douglas et al., 2007).

Next, as explained earlier, zirconia cores were cleaned again in the ultrasonic bath and veneered by a dental technician. A mold was fabricated from silicone putty impression material to control the porcelain thickness. Each zirconia specimen was placed in the mold, then veneering ceramic slurry was condensed over the specimen and hand-vibrated. Absorbent paper tissues removed excess moisture. Base dentin porcelain powder (VITAVM 9 Base Dentine – VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) was applied with 0.4 mm thickness and fired in a ceramic furnace (VITA VACUMAT 250; VITA Zahnfabrik, Germany) at 950°C. The thicknesses of the specimens were controlled with a digital caliper (INSIZE 1108-150, INSIZE CO., China). The excess ceramic material was removed with a diamond rotary cutting instrument (863-204-016; Gebr Brasseler GmbH, Lemgo, Germany) until the 0.3 mm thickness of dentin ceramic was achieved. Specimens were cleaned again, and transparent dentin porcelain powder (VITA VM®9 Transparent Dentine – VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) was applied to the base dentin with approximately 0.9 mm thickness. Samples were sintered in the furnace at 910°C, adjusted, and measured to ensure an overall thickness of 1.56±0.04 mm. Eventually, they were cleaned and glazed at 910°C (Fig. 1). As explained earlier; the specimens were cleaned in the ultrasonic bath and subjected to colorimetry after porcelain veneering.

Statistical software (IBM SPSS Statistics v21; IBM Corp) was used for data analysis. Normal data distribution was evaluated using the one-sample Kolmogorov-Smirnov test, which showed that the TP and ΔE data were normally distributed in all groups ($P$>.05). Thus, the groups were compared using one-way analysis of variance (ANOVA) followed by Tukey's Honest Significant Difference (HSD) for pairwise comparisons. Paired sample t-test was applied to assess the effect of porcelain veneering on TP and $\Delta E^*$. The $\Delta E^*$ values were compared with perceptibility (ΔE=2.6) and acceptability (ΔE=5.5) thresholds (a=.05 for all tests).

## 3. Results

### *3.1.TP*

The results of the mean translucency values of the groups before and after porcelain veneering are shown in Table 2. One-way ANOVA revealed a significant difference in translucency among the zirconia core and veneered groups (*P*<0.001). Paired t-test revealed that the translucency of the samples significantly decreased in all groups after porcelain veneering compared with baseline (P<0.001). Pairwise comparisons by Tukey HSD revealed a significant difference in translucency between all zirconia core groups except for B-A2 and A3-A4 groups (*P*<0.001). The same result was found among the veneered groups.

*3.2.ΔE:*

The mean $\Delta E^*$ between the groups against the same background before and after porcelain veneering is shown in Tables 3 and 4. Between-group comparison of $\Delta E^*$ by one-way ANOVA revealed a significant difference among the groups against both backgrounds (*P*<0.001, Tables 3 and 4). Paired t-test showed thatΔE between the groups decreased after porcelain veneering compared with baseline in all groups (P<0.001, Tables 3 and 4).

Results showed that, against a black background, $\Delta E^*$ of all groups, except for A3-A4, was above the perceptible threshold (ΔE=2.6) before porcelain application, while the values for all groups decreased to a level lower than the perceptible threshold after porcelain application (Table 3 and Fig.2). Against a white background, $\Delta E^*$ of all groups was above the perceptible threshold before porcelain application. However, after it, $\Delta E^*$ of all groups was below the perceptible threshold except for groups B-A3 and B-A4, in which ΔE was between the perceptible and acceptable thresholds (2.6<ΔE<5.5) (Table 4 and Fig.3).

## 4. Discussion

This study aimed to investigate the effect of different pre-colored zirconia copings on the color and TP of zirconia veneered restorations. The results indicated that pre-colored zirconia copings and porcelain veneering significantly affected the TP and color of the final restoration. Thus, the null hypothesis was rejected. In the present study, TP was calculated as the difference in luminance when the material is assessed upon ideal black versus white background. The TP between B-A2 and A3-A4 cores was not significantly different. However, increasing the chroma of zirconia cores decreased the TP values, possibly due to either more or darker pigmentation in the samples with high chroma content that affected the light reflection(Spyropoulou et al., 2011). Tuncel et al. evaluated the effect of different colors of zirconia frameworks on TP and found that the coloring procedure reduced the translucency of zirconia copings(Tuncel et al., 2013).However, Kim and Kim stated that the number of coloring liquid applications with a single shade does not change the translucency of monolithic zirconia significantly(Kim & Kim, 2014).

Kurtulmus-Yilmaz and Ulusoy evaluated the translucency parameter of pre-shaded and colored zirconia cores before and after porcelain veneering. They found that by the increase in chroma of pre-shaded zirconia cores but not colored zirconia copings, the translucency decreased. They suggested that pre-shaded blocks might provide more homogeneous and intense shade than immersion(Kurtulmus-Yilmaz & Ulusoy, 2014). Further, the results demonstrate significant differences in the TP values between all veneered groups except for the B-A2 and A3-A4 groups. However, Harada et al. found no significant difference between the TP of different zirconia core colors (0.5-mm-thick Katana zirconia coping) after ceramic veneering (1-mm-thick Cerabien ZR veneering ceramic)(Harada et al., 2015). These contradictory findings may be associated with different zirconia brands, sintering conditions, application of different porcelain layers (opacious body instead of base dentin in the present study), and use of different porcelain veneering color shades.

Spyropoulou et al. evaluated the TP of pre-colored zirconia cores. They found a significant difference in TP of light and intense, medium and intense shades, but no significant difference was noted between the light and medium shades(Spyropoulou et al., 2011). In the present study, if we assume bleach is a light shade, A2 a medium shade, and A3 and A4 as intense shades, we can find out the reason why the TP of B and A3, B and A4, A2 and A3, and A2 and A4 groups was significantly different both before and after porcelain application. However, the difference between B and A2 and A3 and A4 groups was insignificant before and after porcelain application. Moreover, data showed that in 1 mm thickness of ceramic veneering, the translucency of the samples significantly decreased in all groups after porcelain veneering compared with a baseline which is consistent with what has been found in previous studies(Harada et al., 2015; Jeong et al., 2016; Kurtulmus-Yilmaz & Ulusoy, 2014; Tabatabaian, Aflatoonian, et al., 2019; Tabatabaian, Jafari, et al., 2019).The possible reasons for this decrease include the crystal volume and size of veneering ceramic, increased specimen thickness, reflectance at the interface between the core and veneering porcelain, porosity between the layers, and any changes in the constituent core material with additional firing cycles(Heffernan et al., 2002).

Findings revealed that ΔE between pre-shaded and non-shaded frameworks was greater than ΔE between two pre-shaded cores. In addition, ΔE of all zirconia frameworks was above the perceptible threshold except for ΔE between A3-A4 against the black background. This finding means dark pigmentation and high chroma in either zirconia core or background decrease color difference. Donmez et al. evaluated different mechanical properties and the color difference between pre-shaded, non-shaded, and non-shaded zirconia samples immersed in coloring liquid at different times. As immersion time increased, ΔE between samples with high chroma decreased against grey background(Donmez et al., 2021).

A further finding is that porcelain veneering reduces the color difference between two samples more efficiently than high chroma content. Porcelain veneering reduced ΔE to a level lower than the perceptible threshold for all samples except for B-A3 and B-A4 against the white background. Therefore, it can be deduced that samples look more similar after porcelain veneering with either a pre-colored or non-colored zirconia framework. A pre-colored zirconia core may not be necessary to reach a target color, especially against a dark background. In other words, dark tooth or core build-up material could have porcelain-veneered zirconia restorations with either pre-colored or colorless core and produce a clinically acceptable color match with adjacent teeth. However, composite core or bleached teeth should not have intense pre-colored coping since the color mismatch between adjacent sound teeth and porcelain-veneered zirconia restorations may be perceptible. In this regard, an essential factor to note is the veneering ceramic thickness. Sinmazisik et al. reported that zirconia-based restorations with a zirconia coping thickness of less than 0.5 mm and a dentin veneering ceramic thickness of 1 mm resulted in an ΔE value of more than 5.5 (a color mismatch). However, an increase in the dentin veneering ceramic thickness from 1 to 1.5 mm resulted in an ΔE value of less than 2.6 (a color match)(Sinmazisik et al., 2014).Therefore, in the present study, the color mismatch between B-A3 and B-A4 against the white background might be imperceptible if we increase the ceramic thickness by more than 1mm.

The appropriate thresholds of perceptibility and acceptability used in color studies have been discussed(Douglas & Brewer, 1998; Khashayar et al., 2014; Vichi et al., 2011). The perceptibility threshold represents the smallest color difference detected by expert clinicians, while the acceptability threshold concerns the ability of an untrained observer to ascertain color differences(Tabatabaian, Jafari, et al., 2019). In the present study, the perceptibility threshold was used as a criterion for comparing the findings, and according to Douglas et al.(Douglas et al., 2007), ΔE* =2.6 was used. Because all influential factors in the subject of color were not evaluated in this study, the perceptibility threshold of ΔE* =2.6 rather than the acceptability threshold of ΔE* =5.5 was regarded for evaluating color differences.

There are several limitations to this study. First, TP and ΔE were calculated against white and black backgrounds, which does not perfectly simulate the oral clinical setting. Second, different parts of restoration have variable thicknesses in the clinical setting resulting in variations in TP and ΔE; however, square-shaped samples were used in this *in vitro* study third, the effect of different factors such as cement, glaze, different material brands, and sample thickness did not evaluate in this study. These limitations are suggestions for consideration in future studies.

## 5. Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The zirconia core color can significantly affect the TP and ΔE of all-ceramic restorations, which may be clinically perceptible.

2. Increasing the chroma and porcelain veneering decreased the TP.

3. porcelain veneering is more efficient in reducing ΔE between two samples than high chroma content. A pre-colored zirconia core may not be necessary to reach a target color, especially against a dark background.

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**Table 1**. Materials used.

| materials | Manufacturer | Ceramic shade |
|---|---|---|
| Zirconia | | |
| inCoris TZI C | Dentsply Sirona, Germany | A2, A3, A4 |
| inCoris TZI | Dentsply Sirona, Germany | bleach |
| Veneering ceramic | | |
| VM 9-Base Dentine | Vita Zahnfabrik, Germany | 2M2 |
| VM 9-Transpa Dentine | Vita Zahnfabrik, Germany | 2M2 |

**Table 2.** Mean TP of the groups before and after porcelain veneering

| Groups | Mean ± std. deviation | | Paired t-test result |
|---:|---:|---:|---:|
| | Zirconia core | Zirconia core + porcelain veneering | *P*-value |
| B | 13.17± 0.41$^{a}$ | 8.22 ± 0.45$^{a}$ | 0.001> |
| A2 | 13.11±0.46$^{a}$ | 7.97±0.24$^{a}$ | 0.001> |
| A3 | 12.04±0.49$^{b}$ | 7.50±0.44$^{b}$ | 0.001> |
| A4 | 11.740±.39$^{b}$ | 7.14±0.35$^{b}$ | 0.001> |
| ANOVA result | 0.001> | 0.001> | _ |

Different superscript letters in each column indicate significant difference using Tukey HSD ($P$<0.001)

**Table 3**. Mean $\Delta E^*$ of the groups before and after veneering against a black background

| Groups | Mean ± std. deviation | | Paired t-test result |
|---:|---:|---:|---:|
| | Zirconia core | Zirconia core + | *P*-value |

| | | | |
|---|---|---|---|
| | | porcelain veneering | |
| A2-B | 8.23±0.57 | **1.10±0.58** | 0.001> |
| A2-A3 | 3.34±1.07 | **1.02±0.42** | 0.001> |
| A2-A4 | 5.65±0.58 | **1.57±0.48** | 0.001> |
| B-A3 | 11.08±0.89 | **1.75±0.57** | 0.001> |
| B-A4 | 13.38±0.81 | **2.21±0.68** | 0.001> |
| A3-A4 | **2.59±0.74** | **1.14±0.41** | 0.001> |
| ANOVA result | 0.001> | 0.001> | _ |
| Color differences lower than perceptibility threshold in bold (ΔE<2.6) | | | |

**Table 4.** Mean $\Delta E^*$ of the groups before and after veneering against a white background

| Groups | Mean ± std. deviation | | Paired t-test result |
|---|---|---|---|
| | Zirconia core | Zirconia core + porcelain veneering | *P*-value |
| A2-B | 13.99±1.40 | **1.94±0.69** | 0.001> |
| A2-A3 | 5.10±1.63 | **1.30±0.40** | 0.001> |
| A2-A4 | 8.24±0.81 | **2.49±0.52** | 0.001> |
| B-A3 | 18.89±1.51 | 3.02±0.73 | 0.001> |
| B-A4 | 22.05±0.97 | 4.10±0.70 | 0.001> |
| A3-A4 | 3.60±1.08 | **1.54±0.53** | 0.001> |
| ANOVA result | 0.001> | 0.001> | _ |
| Color differences lower than perceptibility threshold in bold (ΔE<2.6) | | | |

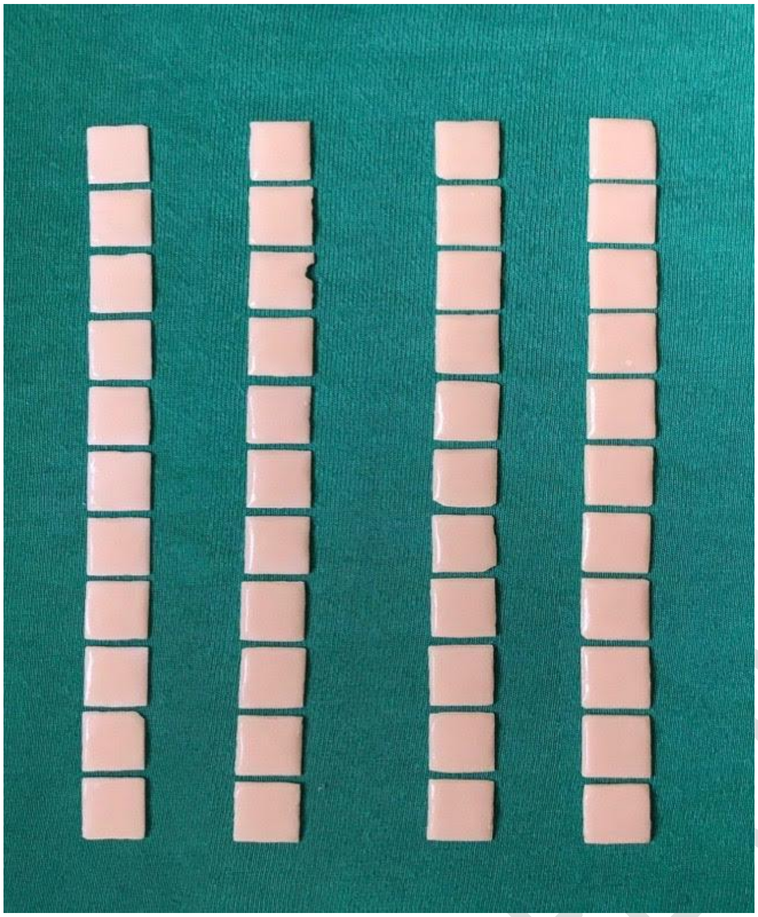
Figure 1. Porcelain-veneered zirconia samples

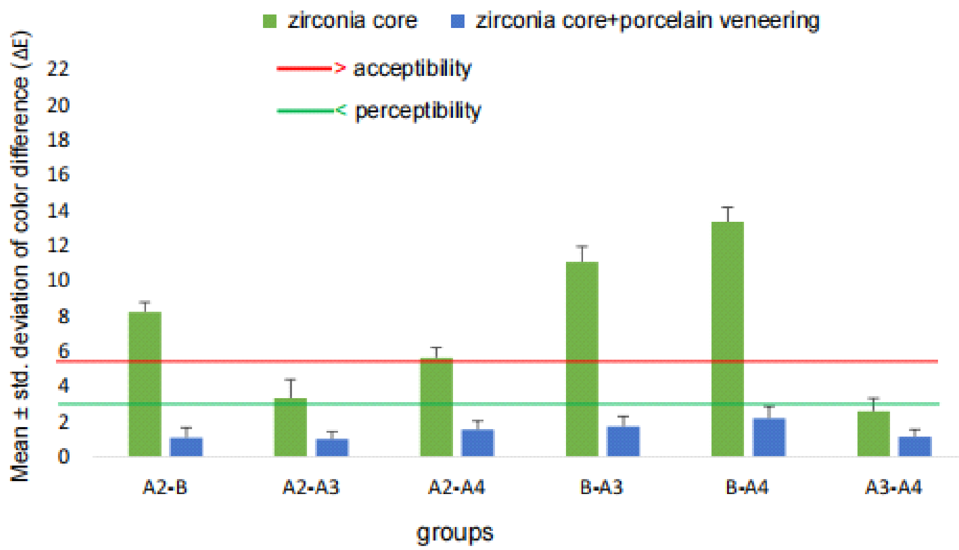


Figure2. Means and standard deviations of color difference (ΔE) values before and after porcelain veneering against a black background.

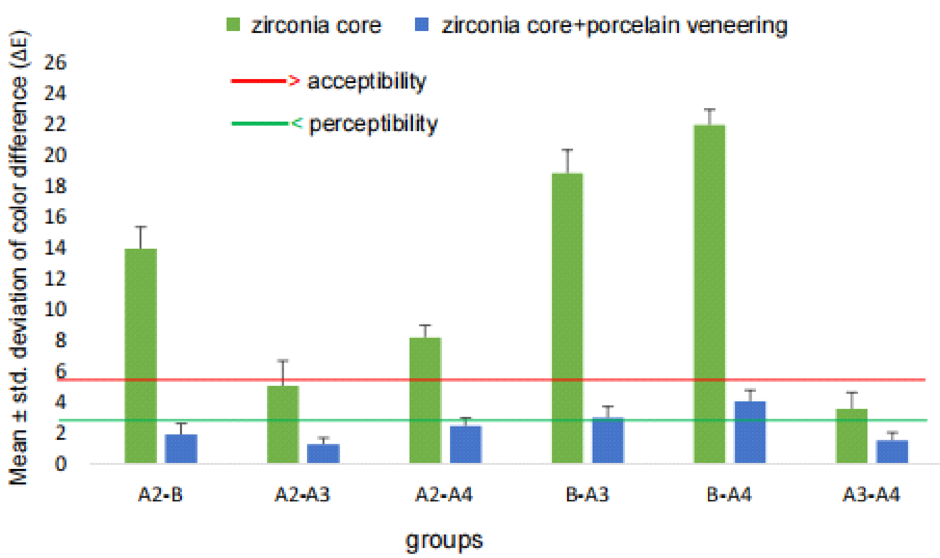


Figure3. Means and standard deviations of color difference (ΔE) values before and after porcelain veneering against a white background.