Influence of framework color and layering technique on the final color of zirconia veneered restorations

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Objective: To investigate the influence of colored zirconia frameworks on the overall color match of zirconia-veneered restorations. Method and Materials: Identical natural and colored zirconia frameworks (Cercon Base, Degudent) were layered using a veneer ceramic (IPS e.max Ceram Dentin, Ivoclar Vivadent) applied either directly on the frameworks, over a thin layer of a masking liner (IPS e.max ZirLiner 1), or over a layer of a deep chroma dentin (IPS e.max Deep Dentin) of the required target color, A1. Color parameters were obtained using a spectrophotometer (Spectro Shade Micro, MHT) and were used to calculate color difference value with the preselected required color (A1 tab according to Vita Classical shade guide). Color difference value < 2.2 was considered a clinically acceptable color match. Results: Only three combinations of tested variables had an acceptable color match compared with the target color: colored zirconia frameworks with liner material or deep chroma dentin and white zirconia frameworks directly layered with the veneer ceramic (P < .001), all tested against a black background. The combination of yellow zirconia with deep chroma dentin over a white background produced a yellowish color shift, while white zirconia frameworks with either liner or deep chroma dentin were brighter and less yellow than the target color (A1). Conclusions: When properly veneered, colored zirconia frameworks could produce clinically acceptable color match and have the capacity to mask a dark background such as a dark tooth or core buildup material. (Quintessence Int 2010;41:e84–e89)

Key words: color, layering technique, zirconia framework

One of the most challenging aspects of all-ceramic restorations is to exactly reproduce the optical qualities of the surrounding dentition, making visual recognition of the inserted restoration a difficult task even for well-trained eyes. Many variables interact together to influence the optical properties of all-ceramic restorations, for example, the morphology of the restoration, its thickness, surface finish, translucency, opalescence, and the layering technique of the veneer ceramic.¹

The achievement of an all-ceramic esthetic restoration that matches perfectly with adjacent teeth is the result of the interplay between two important optical factors: on one hand, the masking capacity of ceramics to block the background color (in many cases, nonvital dentin or a core buildup material) with sufficient material thickness or an opaque masking liner, and on the other hand, the amount of translucency the ceramic that will allow the natural background color shine throughout a translucent material and exhibit the most natural appearance. However, the final color result is unpredictable when the restoration is composed of different layers with unspecified thicknesses, which is the case for core veneered all-ceramic restorations.²
Thanks to its unique mechanical properties, the introduction of partially stabilized zirconium dioxide to the dental field opened new design and application limits of all-ceramic restorations. Nowadays, long span and complex all-ceramic restorations are possible with greater confidence and success rate. As the minimum required thickness of this strong framework does not usually exceed 0.5 mm, the remaining thickness of the restoration is used for building the ceramic veneer. Poly crystalline frameworks such as alumina and zirconia have a natural white color that can negatively influence the final esthetic appearance of the veneered restoration. Therefore, different opaque liner materials are used to mask the natural color of the underlying zirconia framework and to provide an acceptable background color for building the veneer ceramic. However, these liners have proved to weaken the zirconia-veneer bond strength for some commercial systems, which could implicate a higher tendency toward delamination failure. Additionally, application of a liner material further complicates the veneering process and adds a new variable that could significantly influence color match.

Colored zirconia frameworks were recently introduced to the dental market with the aim of enhancing color reproduction of all-ceramic restorations especially in cases where there is inadequate space to accommodate the required thickness of both the framework material and the veneer ceramic (cervical margins and limited interocclusal space). Additionally, they could eliminate the need to apply a masking liner material over white zirconia frameworks. Nevertheless, these new colored frameworks need adjustment of the veneer-application procedure to achieve the required final color. The aim of this study was to investigate the effect of colored zirconia frameworks on the final shade match of zirconia veneered restorations. The proposed null hypothesis was that framework color and layering technique will not have a visually perceptible influence on the overall color match of zirconia-veneered restorations.

METHOD AND MATERIALS

A students’ teaching model with interchangeable acrylic teeth was selected, and a maxillary left central incisor was prepared to receive a standard zirconia-veneered crown restoration. The tooth preparation accounted for 0.9-mm round chamfer margins at the cervical line, 1.2-mm axial reduction, and 1.8-mm incisal clearance. The die was then laser scanned (Cercon Brain, Degudent), and a 0.5-mm zirconia framework was digitally designed using the computer-aided design (CAD) phase of the system. Identical zirconia frameworks were produced by milling natural and colored zirconia blocks (Cercon Base, size 30 mm, Degudent), which were sintered according to manufacturer instructions (Cercon Heat, Degudent, uses a 6.5-hour sintering program at a maximum temperature of 1,350°C).

Layering technique of the veneering ceramic

The produced zirconia frameworks were seated on the prepared resin die and rebuilt to their original anatomical shape using modeling wax (Light green modeling wax, Wieland Dental & Technik), and a silicone mold was fabricated to be used as a template during building of the veneer ceramic, which was layered using three methods.

Group 1: The zirconia frameworks were seated on the prepared die, and the full thickness of the veneer ceramic was directly built using the required target color of the veneer ceramic (IPS e.max Ceram Dentin, A1, Ivoclar Vivadent). A light shade was selected in this study because it had more contrast against the underlying framework and is more sensitive to the influence of the background color. The veneer ceramic was fired according to the manufacturer’s instructions (Austromat 3001, Dekema Dental-Keramiköfen). This group was used to investigate the effect of framework color under the veneer ceramic.

Group 2: A thin layer of a masking liner (IPS e.max ZirLiner 1, Ivoclar Vivadent) was applied and sintered on the zirconia frameworks, followed by building of the veneer ceramic as previously mentioned. This group
was used to illustrate the effect of the masking liner on the final color of the restoration.

**Group 3:** A thin layer of the masking liner was applied on the frameworks and fired, followed by a 0.8-mm-thick layer of a deep chroma dentin ceramic (IPS e.max Ceram Deep Dentin, A1, Ivoclar Vivadent) characterized by its high masking ability, and the rest of the veneer ceramic was produced as previously described. This group was used to evaluate the effect of this special ceramic on the overall color of the restorations. Moreover, this group illustrated the ability of the dental ceramist to produce the required color by incorporating special ceramic slurries in the layering technique.

All veneered specimens were self-glazed as recommended by the manufacturer. Additions of a layer of glaze ceramic could influence color measurement procedure because of its high reflective properties. Twelve identical frameworks were produced for every test group (n = 12).

**Color measurement**

Shade tab A1 (Vitapan Classical, Vita) was selected as the required target color for all fabricated restorations, and accordingly, the corresponding veneer ceramics were chosen. Three color parameters in terms of hue (type of color pigment), chroma (intensity or saturation and purity of color tone), and value (the relative darkness or lightness of hue) were measured using one international color calibration system: Commission Internationale de l’Eclairage (CIE L*a*b* color system), where L represents the lightness from black to white, a* corresponds to red-green axis with a positive value indicating more red, and b* corresponds to yellow-blue axis with a positive value indicating more yellow.

The CIE L*a*b* values of the selected shade tab were measured in a phantom mouth teaching model using a spectrophotometer (Spectro Shade Micro, Handy Dental Type 713000, MHT). To test the influence of background on color match, color measurements of the restorations were performed either against a white die (L* = 98, a* = 0, b* = 3) or a black die (L* = 0, a* = –2, b* = 3). The white die (background) was created by reproducing the master die using a composite resin material (Filtek Supreme, Extra white, 3M ESPE), while the black die (background) was created by wrapping the duplicated master die in a special black cloth (Set#GG470 Black Animal Velvet, Fashion Fabrics Club). The aiming feature of the color-measuring device enabled a reproducible positioning of the device perpendicular to the facial surface of the restoration to ensure equal measurement conditions. Polarization filters were used to eliminate surface gloss. The entire buccal surface of each crown was measured three times using both backgrounds. The data were stored in a proprietary image file format that was used to create detailed CIE L*a*b* data. The difference in color compared to the target color was expressed in \( \Delta E \) values and calculated with the MHT analysis software (Spectro Shade 2.41).

Most studies concerned with color difference between two substrates attain common statistical methods as one-way or repeated-measures analysis of variance (ANOVA). These methods require a big sample size to achieve the required statistical power needed for analysis of small differences between the measured parameters. However, the specimens themselves could have a very low percentage of variance, which is the case with L*a*b* values of the specimens tested in this study. Color difference expressed by \( \Delta E \) value represents the shortest distance in the CIE L*a*b* color space between the color of the restoration and the chosen target color and is calculated using the following equations:

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

\( \Delta E \) value > 2.2 was considered as significant color difference (mismatch) detectable by human eye under clinical conditions. The two-way ANOVA was performed to analyze the data, and Tukey post hoc test was selected for pairwise comparisons (\( \alpha = 0.05 \)). Data were analyzed and examined using SPSS 14.0 (SPSS).
RESULTS

Initial statistical analysis revealed very low percentage of variance among the three measurements made for every specimen (standard deviation less than 2% of the mean value), as well as for the measurements made for the zirconia specimens in every test group. Thus, these values were averaged for every test group and were used to calculate the ΔE value among all specimens and the preselected target color (A1).

The framework color (F = 25.050, P < .001), the layering technique (F = 83, P < .001), and their interaction (F = 4.260, P < .001) had a significant influence on the data obtained. Moreover, the background color strongly influenced the overall color match of the tested restorations (F = 39.341, P < .001).

Only three combinations (measured against the dark background) were successful in producing ΔE value < 2.2: yellow zirconia frameworks with the liner material or deep chroma dentin and white zirconia frameworks directly layered with the veneer ceramic (Fig 1). When tested against a white background, the combination of yellow zirconia with a liner material or deep chroma dentin produced a yellowish color shift and achieved lower ΔE values compared to white zirconia frameworks with either a liner material or deep chroma dentin, which were brighter and less yellow than the target color (A1).

DISCUSSION

The findings of this study indicated that direct application of the required veneer ceramic over natural zirconia framework resulted in accurate reproduction of the required color and was successful in completely masking a dark background color (black die). For colored zirconia framework, application of liner material or deep chroma dentin was necessary to reproduce the required color. Both framework color and layering technique had a significant influence on color match. The proposed null hypothesis was thus rejected. However, it has to be mentioned that using colored zirconia framework did not offer any direct advantage over the standard natural zirconia. On the other hand, using a colored framework required the addition of special ceramics (liner material or deep chroma dentin) to achieve the required color, which could complicate and lengthen the layering procedure.

The three acceptable color matches were achieved when color was measured against a dark background, which indicated that these combinations could also be used in cases of severely discolored dentin and when metallic posts and cores are used to reinforce the remaining tooth structure. It has also to be considered that a white background is rare (bleached teeth or white composite resin core buildup material) and was used in this study to investigate the influence of extreme variations in background color.

According to Johnston and Kao, color mismatch values (ΔE values) below 2.2 are not perceptible to the human eye under most clinical situations. According to this value, the best color match observed in this study was achieved using yellow zirconia framework with liner material (ΔE = 0.76), the second best color match was achieved using a white framework directly layered with the veneer ceramic (ΔE = 1.41), and the least accurate color match was achieved using a yellow framework in combination with deep chroma dentin ceramic (ΔE = 1.98) (see Fig 1). White frameworks with either liner or deep chroma dentin were too bright (high L values) and less yellow than the target color. Similar findings were also observed for alumina-veneered restorations.

A point worth mentioning is that a skillful dental ceramist could reproduce the required target color using either natural or colored zirconia frameworks with the appropriate layering technique. However, to make this process more predictable, the manufacturer of the veneer ceramic should also make more effort to provide the ceramist with guidelines regarding the interaction among these different variables (zirconia, veneer, and special ceramics) to achieve the best color match.

Reproduction of natural tooth color using ceramics is a sensitive procedure. The clinician should first determine the color of the

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new restoration by examining the adjacent teeth visually or digitally. In most cases, clinicians define tooth color by using the code of dental shade tabs that look most similar to the natural tooth (usually the neighboring tooth). Due to the influence of light conditions and other environmental and personal factors on the eye perceptibility, the visual method is inconsistent.

Digital color measurement using Spectro Shade can be considered the gold standard in the dental field, thanks to its consistent illumination, accurate positioning facility, and precise calibration. Therefore, it was used in this study to determine the \( L^*a^*b^* \) values for the preselected color required for all the specimens (A1 shade tab). The test setup used in this study also accounted for reproducing a real clinical environment taking into consideration the influence of the soft tissue (gingival silicone mask of the phantom jaw), dark oral background, and the anatomical position and location of the surrounding dentition.

The selected tooth preparation was based on the standard recommendations for preparations used for all-ceramic restorations keeping in mind to preserve as much of the sound tooth structure as possible. Aggressive preparations that incorporate a deeper chamfer or shoulder finish lines will result in more room for building the veneer ceramic and create better opportunity for producing good color match. However, this would be at the expense of precious tooth structure. In this study, color was measured in the center of each restoration, but under real clinical conditions, the cervical margin is actually the most influenced region by the color of the underlying zirconia framework. This is because the total thickness of the restoration in this region is limited by its emergence profile and marginal properties. Therefore, the results of this study represent only general guidelines, and further studies are still needed to fully elaborate on the tested variables.

Despite the fact that statistical analysis revealed significant differences among the tested groups, some differences were related to color differences that were below the clinically detectable level (\( \Delta E < 2.2 \)). This means that significant differences according to ANOVA can, in reality, represent acceptable color match. Thus, the magnitude of \( \Delta E \) could produce more clinically relevant data compared to the standard statistical methods used for other analytical purposes (see Fig 1).

Color reproduction is one of the most challenging arts in esthetic dentistry and is significantly influenced by the methods used to measure, transfer, and reproduce color. This challenge becomes even more obvious when there is a need to investigate the exact role of different variables on the overall appearance of all-ceramic restorations to produce guidelines for both clinicians and ceramists.
CONCLUSION

When properly veneered, colored zirconia frameworks produced acceptable color matches and were able to completely block a dark background.

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REFERENCES


