Effect of Cement and Abutment Colors on Esthetic Outcomes of Highly Translucent Multilayered Monolithic Zirconia crowns

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Abstract

Objective: To identify appropriate abutment–cement combinations for color matching of 1.2 mm-thick, A2 shade, highly translucent multilayered monolithic zirconia (HTMMZ) crowns.

Material and Methods: Abutments of A2 composite resin, A4 composite resin, and metal were fabricated along with seven 1.2 mm-thick, A2 shade HTMMZ crowns. Three try-in pastes (clear, universal, and opaque) were used as luting agents. Abutment-cement combination specimens were prepared by luting each crown on each abutment type using one of each luting agents. All specimens were assessed using spectrophotometry and then compared with the Katana A2 shade tab (control) to establish the color difference. A color difference of < 2.7 was necessary to be considered clinically acceptable. The data obtained were statistically analyzed using two-way ANOVA followed by post hoc Tukey's test ($\alpha = 0.05$).

Results: Abutment and cement colors and their interaction affected ΔE_{ab} ($p < 0.05$). The A2 abutment-clear cement, A2 abutment-universal cement, A4 abutment-clear cement, and A4 abutment-universal cement groups showed the lowest values almost reached an acceptable color match. Unacceptable color matches were observed in all the cement and abutment groups.

Conclusions: For the A2 and A4 abutment, crowns luted with universal cement almost reached a clinically acceptable color match. And for the silver-palladium metal abutment, crowns luted with opaque cement showed lower ΔE_{ab} value compared to clear and universal cement.

Keywords: Abutment color, Cement color, Color difference, Esthetics, Masking ability

Received Date: Dec 08, 2022
Revised Date: Mar 14, 2023
Accepted Date: Mar 17, 2023

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Introduction

Restoring maxillary incisors is esthetically challenging. Esthetic restorations should replicate the shape, contour, texture, translucency, and color of adjacent teeth.

Over the past decade, zirconia alternatives to metal substructures have been widely used for dental restorations. Three mol percent yttria-stabilized tetragonal zirconia has excellent physical properties owing to the transformation toughening process (1), high biocompatibility, and high chemical stability (2). However, the whitish opaqueness of zirconia affects the overall translucency of the definitive restoration. Therefore, previously, the zirconia core would be veneered with feldspathic porcelain to fabricate esthetic restorations. However, chipping of veneering porcelain is problematic (3-5). Pre-colored monolithic zirconia was developed using metal oxides to overcome the issues caused by the bilayered structure. Additionally, to improve translucency, 4 and 5 mol% yttria-tetragonal zirconia polycrystals (4Y-TZP and 5Y-TZP) were developed; however, these materials also possess weak mechanical properties (6). Subsequently, highly translucent multilayered monolithic zirconia (HTMMZ) was developed to achieve both high strength and acceptable translucency. It comprises layers of different zirconia materials: high-strength 3Y-TZP at the bottom to simulate central dentin with a gradual transition to a reduced strength 4Y-TZP and/or 5Y-TZP in the central and incisal areas (7-9). However, the colors of the abutment and resin luting cement reflect through this highly translucent material and affect the final restoration color (10). Resin luting cement is commonly used with highly translucent restorative materials (11), and together with pretreatment of the zirconia crown intaglio surface, it exhibits higher crown retention compared to that by resin modified glass ionomer cement (12). Resin luting cements of a variety of shades are available in the market with corresponding try-in pastes. The final luting cement shade is determined by first using the try-in paste before final cementation. Try-in pastes correspond with their respective resin cements for most colors investigated (13). Daneshpooy et al. (14) found better shade agreement between try-in pastes and their respective resin cement for thicker highly translucent multilayered zirconia and for lighter shades.

Color is an important determinant when trying to mimic the adjacent natural teeth. Visual shade matching utilizing the dental shade tab is common in clinical practice to compare crown colors. However, in dental color research, spectrophotometry is considered the gold standard to measure color (15,16). It quantitatively measures color and translucency based on the Commission Internationale de l'Eclairage (CIE) LAB (ΔEab) color coordinates, where *represents the lightness of the object and a* and b* represent the position of the color on the blue/green to red/purple axis and the purple/blue to the yellow axis, respectively (17). It can be used to calculate the color difference between two objects (ΔE). The 50/50% perceptibility threshold refers to when 50% of observers can detect color differences, and the 50/50% acceptability threshold refers to when 50% of observers decide to remake the restoration due to a clinically apparent color mismatch (18). The effects of the colors of the luting cement and underlying abutment and the material thickness on the final color of a highly translucent restorative material has been studied; however, most studies examined non-anatomically shaped specimens of mono color zirconia blanks, used a flat background color (19-22), or did not use luting cement between zirconia and the background interface (22,23). Although some studies have tested the final color of zirconia crowns with an anatomical contour, no information on the effect of metal abutments and opaque cement is available (24,25). Moreover, relevant studies on HTMMZ are sparse.

Therefore, this in vitro study aimed to evaluate the color differences (ΔE_{ab}) between 1.2 mm-thick, A2 shade HTMMZ crowns with different cement color-abutment type combinations and the Katana A2 shade tab as the control.

Material and Methods

1. Artificial tooth preparation

An artificial maxillary left central incisor (A55a-211; Nisshin, Kyoto, Japan) was prepared using a D8 tapered round end diamond bur (intensive, Montagnola, Switzerland) to create a 1 mm round chamfer with a 1.2 mm midlabial reduction and 1.5 mm incisal reduction.

2. Abutment fabrication

An impression of the prepared tooth was made using a regular body polyvinyl siloxane impression material (Examixfine Regular; GC, Tokyo, Japan) to create an impression mold.

A2 and A4 shade abutments with handles were made by filling and light-curing composite resin (Clearfil AP-X, Kuraray Noritake Dental, Okayama, Japan) incrementally in the mold.

A metal abutment was made using GC pattern resin (GC, Tokyo, Japan) filled in the impression mold and cast with silver-palladium metal (Auro W-lite, Aurium, California, USA) according to the manufacturer’s instructions. The 1.5-mm-ferrule and handle for the metal abutment were made of A2 shade composite resin (Fig 1).

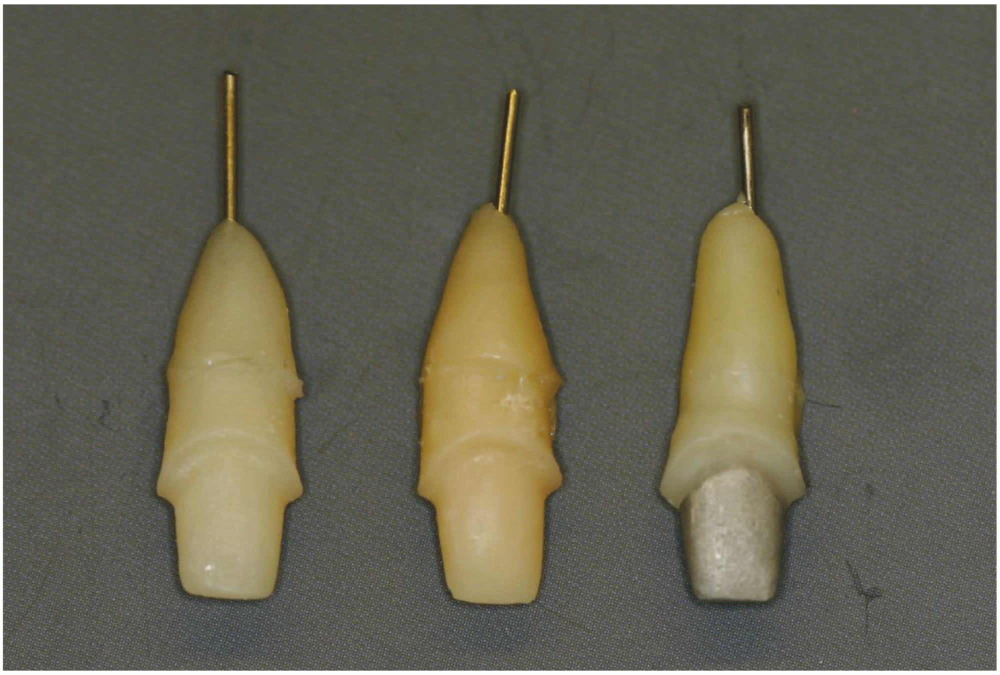

Fig 1. A2 (left), A4 (middle), and metal (right) abutments.

3. Crown fabrication

The prepared artificial teeth were scanned using a rainbow scanner (Dentium, Seoul, Korea). Seven A2 shade HTMMZ (KATANA Zirconia STML Kuraray Noritake Dental, Tokyo, Japan) maxillary left central incisor crowns were designed with a midlabial thickness of 1.2 mm and cement space of 50 μm using a three-dimensional design software (Exocad DentalCAD; ExoCAD GmbH, Darmstadt, Germany) (Fig 2). All crowns were fabricated using a computer-aided manufacturing system (Rainbow Mill-Zr, Dentium, Seoul, Korea). The specimens were placed upright at the center of the A2-shade monolithic multilayered precolored zirconia disks so that each specimen included all layers. All specimens were sintered at 1530°C for 8 h in a high-temperature furnace, following the manufacturer’s instructions.

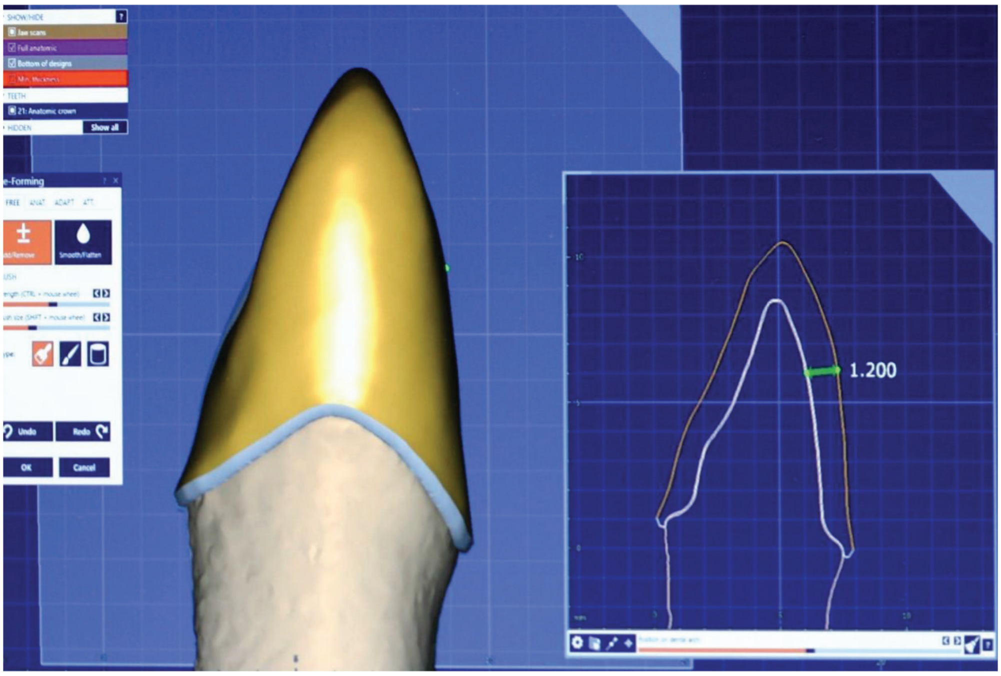

Fig 2. Maxillary left central incisor crowns with a midlabial thickness of 1.2 mm and cement space of 50 μm were designed with a three-dimensional design software (Exocad DentalCAD; ExoCAD GmbH, Darmstadt, Germany).

4. Fabrication of abutment-cement combination specimens

Three colors of try-in paste (clear, universal, and opaque Panavia V5 try-in paste; Kuraray Noritake Dental, Okayama, Japan) were used as luting agents. Each luting agent was applied to crowns on each abutment type (Fig 3).

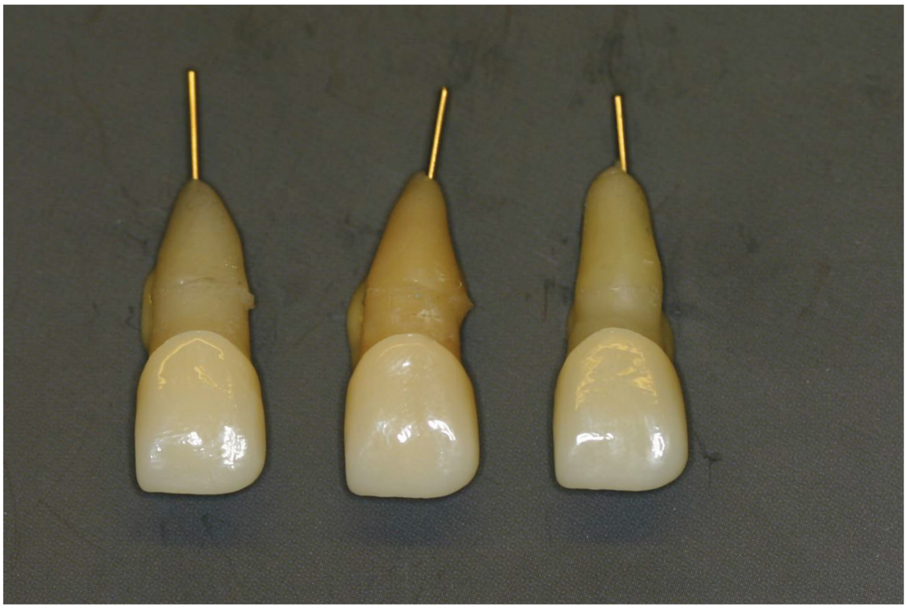

Fig 3. A2 shade highly translucent multilayered monolithic zirconia (KATANA Zirconia STML Kuraray Noritake Dental, Tokyo, Japan) crowns on A2 (left), A4 (middle), and metal (right) abutments using the clear cement shade.

The control group was created by using the Katana A2 shade tab. Nine test groups were designed based on the combinations of each abutment (A2, A4, and metal abutments) with each luting cement (clear, universal, and opaque) by repeated application of the seven crowns. The materials used in this study are listed in Table 1.

Table 1. Composition and manufacturers of the materials.

Category	Material	Manufacturer
A2 shade abutment	A2 light-cured composite resin	Clearfil AP-X, Kuraray Noritake Dental, Okayama, Japan
A4 shade abutment	A4 light-cured composite resin	Clearfil AP-X, Kuraray Noritake Dental, Okayama, Japan
Metal abutment	silver-palladium metal	Auro W-lite, Aurium, California, USA
Clear cement	Clear try-in paste	Panavia V5, Kuraray Noritake Dental, Okayama, Japan
Universal cement	Universal try-in paste	Panavia V5, Kuraray Noritake Dental, Okayama, Japan
Opaque cement	Opaque try-in paste	Panavia V5, Kuraray Noritake Dental, Okayama, Japan
A2 shade crown	Highly translucent multilayered monolithic zirconia	KATANA Zirconia STML Kuraray Noritake Dental, Tokyo, Japan

5. Data collection of color composition and differences

After preparing all specimens, they were promptly set on a specimen holder inside a black box. The color coordinates at exactly the center of the middle-third portion of all specimens were immediately assessed using a spectrophotometer (EasyshadeV, Vita, Yorda Linda, North America). The color composition of each specimen was recorded. The color differences (ΔEab) between the test and control groups were calculated based on the following CIELab (ΔEab) formula:

$$\Delta E_{ab} = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{½}.$$

The color acceptability threshold of ΔE_{ab}= 2.7 was used to determine a clinically acceptable color match (26).

6. Statistical Analyses

In this study, we found a significant difference in the statistical power of the test with 63 subjects (7 subjects per group) (G*Power 3.1.9.4; Department of Psychology, Christian-Albrechts-University, Kiel, Germany). The Shapiro–Wilk test was used to check for normal distribution and homogeneity before statistical analysis of the data using two-way analysis of variance (ANOVA) (SPSS 21.0, SPSS, Inc., Chicago, IL, USA). For multiple comparisons, Tukey's post hoc test was used with a significance level of 0.05 (α = 0.05).

Results

Two-way ANOVA showed that the cement and abutment colors and the interaction between the two factors significantly affected the mean color differences (ΔEab) of HTMMZ crowns ($p < 0.05$) (Table 2).

For metal abutments, there were statistically significant ($p < 0.05$) differences in color between the opaque and other two cement groups, but no statistically significant difference was found between clear and universal cement groups. In the A2 and A4 abutment group, there were statistically significant ($p < 0.05$) differences in color between the opaque and universal cement groups, but no statistically significant difference was found between clear and other two cement groups (Table 3).

When the acceptability threshold was 2.7, crowns luted with clear and universal cement on the A2 and A4 abutments almost reached an acceptable color match. Unacceptable color matches were observed in all the cement and abutment groups. Utilizing opaque cement in the metal abutment group can lower ΔE value significantly compared to other cements. The lowest ΔE value was found in A2 abutment luted with universal cement. The highest ΔE value was found in metal abutment luted with clear cement (Fig 4).

Table 2. Two-way ANOVA results of mean ΔE values.

Source	SS	*df*	MS	F	p
abutment color (A)	74.565	2	37.282	65.617	< 0.05
cement shade (B)	3.839	2	1.920	3.379	< 0.05
A×B	33.530	4	8.382	14.753	< 0.05
Error	30.682	54	0.568		
Total	1328.332	63			

$p < 0.05$ indicates significant difference.

Table 3. Mean ΔE_{ab} values and 95% confidence intervals with statistical summaries.

	Abutment color		
Cement shade	**A2**	**A4**	**Metal**
Opaque	4.24 (3.43-5.05)^{bc}	4.58 (4.01-5.16)^{b}	4.53 (3.81-5.24)^{b}
Clear	3.10 (2.49-3.72)^{cd}	3.78 (3.20-4.36)^{bcd}	6.82 (5.83-7.81)^{a}
Universal	2.82 (2.38-3.26)^{d}	2.93 (2.53-3.33)^{d}	6.26 (5.33-7.14)^{a}

*Results of Tukey HSD post hoc comparisons are shown as superscript letters, and values with the same superscript letters are not significantly different ($p > 0.05$).

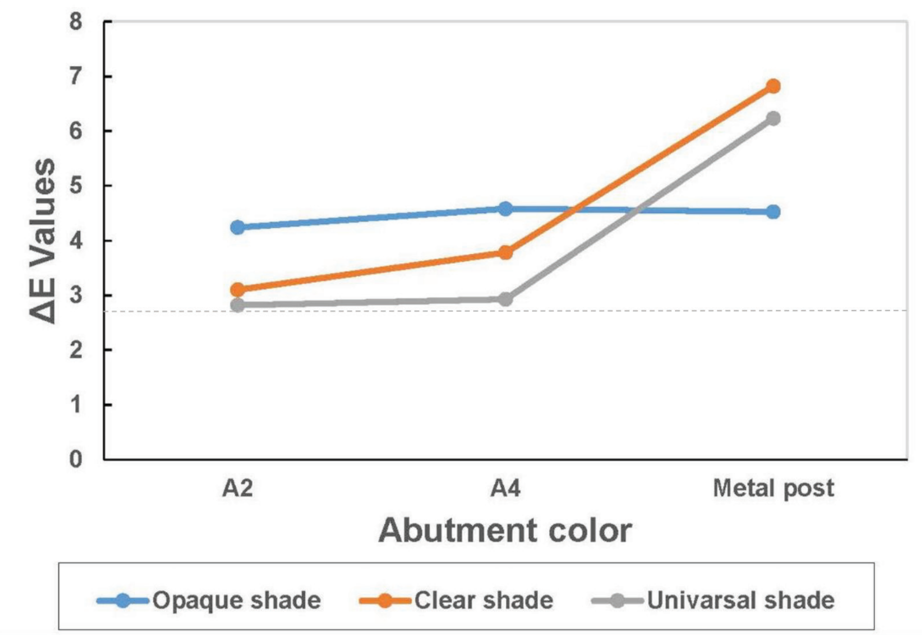

Fig 4. Mean ΔE values for cement shade and abutment color.

Discussion

The goal of this study was to evaluate the ΔE_{ab} between HTMMZ crowns placed using different combinations of cement colors and abutments, with the control groups using the Katana A2 shade tab. The results demonstrate a correlation of cement and abutment colors and the interaction between the two factors with the ΔE_{ab} of HTMMZ crowns. The A2 abutment-clear cement, A2 abutment-universal cement, A4 abutment-clear cement, and A4 abutment-universal cement groups showed the lowest values. Based on the power calculation, the sample size was adequate and effective.

In 2020, Juntavee and Kornrum (27) found that the fracture resistance of highly translucent monolithic zirconia crowns with a deep chamfer margin (1.2 mm) is greater than that of zirconia crowns with a slight chamfer (0.8 mm). However, crowns of both margins types were capable of withstanding a fracture load higher than the maximum masticatory force of humans (27). In 2021, Prott et al. found that 3Y-TZP monolithic zirconia crowns with a layer thickness of > 1.0 mm could withstand a simulated 5-year clinical application without fracture (28). However, 4Y-PSZ and 5Y-PSZ translucent zirconia materials are associated with inferior mechanical properties because phase transformation toughening is absent due to the predominance of the cubic phase (29-31). The failure load and thermomechanical longevity of 4Y-TZP and 5Y-TZP crowns has not yet been investigated. In addition, there is no consensus on how thin this restoration may be fabricated. For the clinical success of the crown, a low film thickness should also be considered to improve restoration seating and decrease marginal leakage (32). However, the masking effect is based on the thickness of the cement layer (33). The A2 shade has been used in many previous studies on highly translucent zirconia (10,22,34,35). For the aforementioned mechanical and esthetic properties, HTMMZ crowns of A2 shade with a 1.0 mm round chamfer and midlabial reduction of 1.2 mm were used in this study, and a cement thickness of 50 µm was set to make our findings more clinically relevant.

Considering abutment color, A2 shade abutments were representative of the normal tooth color, and the A4 shade represented the darkest abutment color as a result of the conversion of the darkest color (5m3) in the Vita 3D master scale (36). Metal abutments represented metal post or implant metal abutments used clinically.

Although it has been found that sintering and positioning of restorations within a multilayered zirconia blank have little effect on the fracture resistance of the prosthesis (37), they may have affected the color of each specimen. To reduce the fabrication variation between each crown, all crowns were fabricated by the same technician. The spectrophotometer was calibrated according to manufacturer instructions. The same researcher was responsible for measuring the color of all crowns, cement color, and abutment color under the same light and positioning using the specimen holder throughout the measuring step to minimize measurement variation.

The results of this study are in accordance with those of previous studies that the final color of highly translucent zirconia is affected by the abutment and cement colors (19,23,24,38). Tabatabaian et al. (23) found that on placing highly translucent zirconia of 1.1 mm thickness on A2 composite resin and metal backgrounds, the ΔE_{ab} values ranged between 2-3 and 5-6, respectively. However, in their study, only distilled water was placed between the specimen and substrate. In the present study, try-in cement was also used to simulate the clinical scenario, and we found that cement color also affected the accuracy of the final color, which confirmed the findings of Bayindir et al. (19,38) The results of the present study were similar to those of Bayindir et al. (19), who also used A2 Katana highly translucent zirconia specimens of various thicknesses between 0.5 and 2.0 mm placed them over clear or opaque Panavia V5 cement. The ΔE_{ab} of 1 mm-thick zirconia placed over clear cement was approximately 2-3 while that of zirconia placed over opaque cement was around 6-7. As the thickness of the specimens increased, their ΔE_{ab} decreased.

There is consensus that the ΔE value is appropriate for determining color mismatch in dentistry. However, the perceptibility and acceptability thresholds vary between studies. There is universal standard for the threshold value. Khashayar et al. showed that most dental studies have used the perceptibility threshold of ΔE_{ab} = 1, and one-third of these have used an acceptability threshold of ΔE_{ab} = 3.7 (39). Tolerance for perceptibility was significantly lower than that for acceptability in case of shade mismatch (40). Many studies on zirconia-based restorations have also used an acceptability threshold of ΔE_{ab} = 3.7 (19,35,41). However, Paravina et al. reported an acceptability threshold of ΔE_{ab} = 2.7 which delivers an up-to-date and more precise parameter (26).

In this study, the final color of A2 shade HTMMZ crowns with 1.2 mm labial thickness luted with clear and universal cement on the A2 and A4 abutment almost reached an acceptable color match. Unacceptable color matches were observed in all the cement and abutment groups. This can be explained as follows:

1. For A2 abutment, ΔE_{ab} for crowns luted with opaque cement (4.24 ± 0.88) was higher than that with universal (2.82 ± 0.48) and clear cements (3.10 ± 0.66). And for A4 abutment, ΔE_{ab} for crowns luted with opaque cement (4.58 ± 0.62) was higher than that with universal (2.93 ± 0.43) and clear cements (3.78 ± 0.63). Moreover, there were statistically significant ($p < 0.05$) differences in color between the opaque and universal cement groups, but no statistically significant difference was found between clear and other two cement groups.

This finding proved that the masking effect of the HTMMZ crown was adequate for the dark underlying A4 abutment but inadequate for metal abutments. Therefore, universal cement is recommended for use with the A2 and A4 abutment.

2. For metal abutments, ΔE_{ab} for crowns luted with opaque cement (4.53 ± 0.78) was lower than that with universal (6.26 ± 0.98) and clear cements (6.82 ± 1.07). And there were statistically significant ($p < 0.05$) differences in color between the opaque and other two cement groups, but no statistically significant difference was found between clear and universal cement groups. Utilizing opaque cement in the metal abutment group can lower ΔE value significantly compared to other cements.

This finding suggested that the masking effect of clear cement was not enough to hide the dark underlying abutment as no acceptable color match in the metal abutment group was found in all cements tested. The result of the present study is in agreement with that of Kang et al., who found that the final color of 1.0-1.5 mm-thick Katana STML zirconia over a gray background without cement was clinically unacceptable. There was, however, no cement tested in this study (35).

Although, cement color was required to decrease ΔE for metal abutments. The results of previous studies have shown that opaque cement can mask metal abutments (38,42). In this study, it was proven that the masking effect of opaque cement on metal abutments is effective. Therefore, opaque cement is recommended for silver-palladium metal abutments.

Nevertheless, the final color may still be mismatched despite using opaque cement on metal abutments. Not only does the cement color and layer affect the final color of a translucent material (19,20,33,38,43), but the restoration itself. The thicker the material, the greater the reduction in ΔE (19,20,38). Moreover, the optical properties of the materials as well as different compositions of the materials at 1.2-mm-midlabial thickness of A2 shade HTMMZ crowns (body layers 1 and 2 of KATANA™ Zirconia STML area) should be considered. This area comprises three zirconia layers, 3Y-TZP, 4Y-TZP, and 5Y-TZP from the inner to outer layer, respectively, due to which the outer surface is more translucent (7-9). This can be explained by a light beam falling on an HTMMZ crown and dividing into reflected, transmitted, and scattered or absorbed light (8). Concerning the high translucency of HTMMZ, the light scattering from the bulk of the material has to be eliminated (8). Its cubic grains are isotropic in contrast with anisotropic tetragonal grains. Therefore, only the 4Y-TZP and 5Y-TZP layers with increased nonbirefringent cubic phase (29) can reduce the high scattering at the grain boundaries, thereby increasing translucency, regardless of the grain size (44,45). In addition, the scattering and absorption characteristics of these three layers in combination contributed to the final translucency in this study.

Hence, to achieve an acceptable final color when using a metal abutment, not only cement but sufficient crown thickness is also needed. The use of only one shade of A2 Katana HTMMZ crowns can be considered a limitation of the current study. Further studies on other shades of zirconia crowns with various thicknesses are recommended.

Conclusions

Our findings indicate the following clinically relevant conclusions for A2 shade HTMMZ crowns of 1.2-mm-midlabial thickness placed on A2 shaped abutments:

1. Abutment and cement colors and their interaction significantly affect the ΔE_{ab} of the crown.

2. For the A2 and A4 abutment, crowns luted with universal cement almost reached a clinically acceptable color match.

3. For the silver-palladium metal abutment, crowns luted with opaque cement showed lower ΔE_{ab} value compared to clear and universal cement.

Data Availability

The data used are included within the article and may also available by email to the corresponding author.

Conflicts of Interest

The authors declared that they have no conflicts of interest

Scholar

Research fund from Faculty of Dentistry, SWU in 2022.

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