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ORIGINAL ARTICLE

Influence of abutment material and luting cements color on the final color of all ceramics

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Abstract

Purpose. The purpose of this study is to evaluate the effects of different abutment materials and luting cements color on the final color of implant-supported all-ceramic restorations. ***Materials and methods.*** Ten A_2 shade IPS e.max Press disc shape all-ceramic specimens were prepared (11 × 1.5 mm). Three different shades (translucent, universal and white opaque) of disc shape luting cement specimens were prepared (11 × 0.2 mm). Three different (zirconium, gold-palladium and titanium) implant abutments and one composite resin disc shape background specimen were prepared at 11 mm diameter and appropriate thicknesses. All ceramic specimens colors were measured with each background and luting cement samples on a teflon mold. A digital spectrophotometer used for measurements and data recorded as CIE L*a*b* color co-ordinates. An optical fluid applied on to the samples to provide a good optical connection and measurements on the composite resin background was saved as the control group. ΔE values were calculated from the ΔL, Δa and Δb values between control and test groups and data were analyzed with one-way variance analysis (ANOVA) and mean values were compared by the Tukey HSD test ($\alpha = 0.05$). ***Results.*** One-way ANOVA of ΔL, Δa, Δb and ΔE values of control and test groups revealed significant differences for backgrounds and seldom for cement color groups (p the 0.05). Only zirconium implant abutment groups and gold palladium abutment with universal shade cement group were found to be clinically acceptable ($\Delta E \leq 3.0$). ***Conclusion.*** Using titanium or gold-palladium abutments for implant supported all ceramics will be esthetically questionable and white opaque cement will be helpful to mask the dark color of titanium abutment.

Key Words: *Implant abutment, luting cement, all ceramic, color, color difference*

Introduction

Rehabilitation of complete or partial edentulism with implant-supported or retained prosthesis has become an appropriate approach for many cases [1]. With recent developments in implant technology, high success rates have been reported for implants placed in partially edentulous arches [2–5]. However, the use of implants to replace missing teeth in the aesthetic zone remains to present significant challenges [5,6]. To achieve an esthetically appropriate implant supported restoration, perfect three-dimensional planning, a proper surgical technique, soft tissue management and a proper prosthetic approach are essential factors [7–10].

All ceramic materials have been widely used, particularly for anterior restorations, to achieve optimal esthetics [11]. All ceramics are generally composed of moderately transparent small particles of different refractive indices. Such composition results in the diffusion of light in many directions with reduction in the intensity of transmitted light causing natural tooth-like translucency and esthetic characteristics [12–14]. On the other hand, metal ceramic restorations sub-structure prevents the transmission of light in the body of the restoration, resulting in a material that looks more opaque and less vital [15,16]. Most recently, all-ceramic restorations have become increasingly popular for restoring teeth and implants. All ceramics' more translucent structure allows more

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Table I. Materials used in this study.

Material	Type	Manufacturer	Shade
IPS e.max Press	Heath pressed Lithium disilicate all ceramic	Ivoclar Vivadent AG (Schaan, Liechtenstein)	A_2 (medium opacity core)
Olympia	Gold-palladium alloy abutment material; 51.5% gold, 38.5% palladium, without silver	F.J. Jelenco (Armonk, NY)	Yellowish grey
Rematitan Ti-4	High-quality pure titanium alloy abutment material; 99% Ti, 0.3% Fe	Dentaurum GmbH & Co. KG (Ispringen, Germany)	Dark grey
Tetric Ceram	Microfill composite resin	Ivoclar Vivadent AG (Schaan, Liechtenstein)	A_2
RelyX Unicem	Dual-polymerized resin cement	3M ESPE (StPaul, MN)	Universal (A_2) Translucent White Opaque
Cargille Optical Gel	Refractive index solution (n = 152)	Cargille Lab (Cedar Grove, NJ)	Colorless

light to enter and scatter, which means that the underlying tooth or abutment, the thickness and color of the luting agent have a significant influence over the resultant color [17–21].

Titanium is the most frequently preferred superstructure material for implant-supported prostheses because of its well documented biologic and mechanical advantages [5,22]. Also the pre-fabricated components simplify the laboratory procedures [23]. However, these abutments do not inherently contribute to the perfect optical properties of natural teeth in the aesthetic zone [5,16,17,24]. Also, these abutments may give the soft tissue an unnatural bluish appearance [5–7,16]. The advantages of all-ceramic restorations cemented over metal abutments are questionable, especially when highly translucent heat-pressed ceramic systems are selected [18,25]. All ceramic abutments, made of aluminum oxide or yttrium-stabilized zirconium oxide, have been produced in an effort to overcome this esthetic problem and ensure better esthetic outcomes for implant-supported fixed partial dentures [5,25–29]. Compared to metal abutments, these abutments offer optically favorable characteristics, low corrosion potential, high biocompatibility and low thermal conductivity. On the other hand, ceramic abutments are weaker then metal abutments [5,27]. Several types of implant abutments can have different effects on the color of all-ceramic restoration for its optical structure.

Implant-supported fixed prostheses can be connected to the osseointegrated implants by screw or cement retention options. Luting cement color may be an important factor, when cement retained implant supported all ceramic restorations are luted over ceramic abutments. Additionally, the color and translucency of a luting cement can alter and modify the dark underlying structure in cases of metallic abutments [21]. It has been demonstrated that the application of luting cements couldn't always manage the color of sub-structure layer and the final color of ceramic restoration affected by the color of underlying material when ceramic thickness decreases to less than 1.5 mm [11,17,21].

Several investigations investigated the effect of metallic and ceramic posts color on the appearance of all ceramic restorations [16–18,30]. However, the impact of using different implant abutments on the final color of all ceramic restorations as well as the masking ability of different shades of luting cements on this effect has never been fully investigated. The purpose of this *in vitro* study was to evaluate the effects of three types of implant abutment materials and three shades of luting cement on the final color of lithium disilicate all-ceramic crowns. The research hypotheses of this study was that the types of abutment materials influence the final color of all ceramic restorations and that luting cements would mask or modify its color.

Materials and methods

Three groups of materials were used in this study. The types of materials are presented in Table I.

Fabrication of ceramic specimens

A teflon mold was prepared to fabricate the wax duplicates of all ceramic core specimens. Ten wax disc-shape specimens were prepared at a diameter of 11 mm and thickness of 0.8 mm [30,31]. In order to prepare wax duplicates, teflon mold cavities were isolated by applying an insulating material (Acry Film, Ruthinium Group, Badia Polesine, Italy), then filled with melted medium-hard modeling wax (Crown wax 40115, Bego, Bremen, Germany) without any air bubble. After the wax duplicates reached sufficient rigidity, they were removed carefully from the cavities. Then wax specimens were bonded in to a 100 gr silicon casting mold and mold was filled using a phosphate investment material (IPS Press Vest Speed Investment, Ivoclar, Schaan, Liechtenstein). After the burn-out procedure, an A_2 shade IPS e.max Press ingot (IPS Empress TC1, Ivoclar, Schaan, Liechtenstein) was heated and pressed according to the manufacturer's instructions. Investment material around the core specimens was removed by sandblasting with 110-μm aluminum oxide particles (Korox 110, Bego) and specimens separated carefully by diamond burs. IPS e.max core discs dimensions were controlled and required adjustments were performed by diamond burs under water cooling.

One side of all ceramic core specimens was ground and smoothed with 600, 800, 1000 and 1200 sanding discs (3M ESPE, St. Paul, MN) on a sanding machine (Phoenix Beta, Buehler, IL) at 100 rev/min for 15 s, under water cooling. Specimens were adjusted at uniform finish surface, thickness and controlled with 5-point measurements using a digital micrometer (Digimatic Caliper, Mitutoyo MC, Kawasaki, Japan). Then A_2 shade nanoflour aphatid veneering ceramic (IPS e.max Ceram, Ivoclar) was layered onto the core discs at a thickness of 0.7 mm. To obtain the desired thickness, a teflon mold at a diameter of 11 mm and thickness of 1.5 mm was used as a reference. Layers were prepared 0.1–0.2 mm thicker than the final desired dimension to compensate for the shrinkage and provide further precise adjustments [30]. Firing was performed according to the manufacturer's recommended procedure. Specimens' final thicknesses were adjusted at a diameter of 11 mm and thickness of 1.5 mm, then an auto-glazing process was performed.

Fabrication of backgrounds

To simulate the mostly used implant abutments, one type of ceramic and two types of metallic (titanium, gold palladium) disc shaped backgrounds were fabricated. Also a composite resin background was fabricated for a control group. Three pattern resin (Pattern Resin, GC America Inc, Chicago, USA) samples were obtained using silicone molds 11 mm in diameter and 0.5 mm in thick. Two pattern resin samples were cast in titanium (Rematitan Ti-4, Dentaurum GmbH & Co. KG, Ispringen, Germany) and gold-palladium (Olympia, F.J. Jelenco, Armonk, NY) alloys according to the manufacturer's instructions. The last pattern was mounted to a MAD-MAM (manual aided design-manual aided manufacturing) machine (Zirkograph 025 ECO, Zirkonzahn, Gais, Italy) and a zirconium specimen was obtained by grinding the pre-sintered Y-TZP (yttria stabilized polycrystalline tetragonal zirconia) block (ICE Zirkon, Zirkonzahn, GmbH, Italy). An A_2 shade resin composite (Tetric Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) disc was fabricated using a silicone mold at a diameter of 11 mm and a thickness of 3 mm to represent normal dentin (control group). The resin composite was placed inside the cavity with an incremental layering technique and light cured with a LED light curing unit (Hilux LED 550, Benlioglu Dental, Ankara, Türkiye) at 750 mW/cm^2 for 20 s for all layers. The resin specimens were then immersed in distilled water at 37°C ± 1°C for 24 h. All background specimens were ground-finished with 600, 800, 1000 and 1200 grit silicon carbide abrasive paper (3M ESPE, St. Paul, MN) for 10 s on a 300-rpm grinding machine. All background discs and composite disc were polished with 300 grit abrasive paper to eliminate the glassy surface.

Fabrication of cement specimens

For the cement specimens, disc shaped cavities were obtained on a hard plastic plate with the use of a sharp punch at 11 mm in diameter and 0.2 mm in thick. Aplicap Capsules which contain the powder and liquid of dual cured resin cement material were mixed and prepared with manufacturer equipment and the recommended procedure. Then, the mixture was placed inside the plastic plate cavities between two polyester strip convoluted glass plates and light-cured with a LED light curing unit at 750 mW/cm^2 for 20 s for both sides. Specimens were extracted from the plastic plate with a slight finger pressure. A total of 30, 10 per each color (universal, translucent and white opaque) cement specimens were prepared at 11 mm in diameter and 0.2 mm in thickness [11,16,17,32]. Cement specimens were then placed in an incubator (EN 055, NUVE A.Ş ., Izmir, Turkey) at 37°C ± 1°C for 24 h for complete polymerization.

Spectrophotometric analysis

The color measurements were performed using a spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Säckingen, Germany) device. A teflon mold with two components was prepared to position the background, cement and ceramic specimens and to position the spectrophotometer measuring tip (6 mm diameter) opposite the center of the specimens (11 mm diameter).

Before each measurement, the spectrophotometer was calibrated using the calibration apparatus according to manufacturer's introductions. First the background specimen was placed in the mold where the polished surface would be the upper side. Then, the translucent shade cement specimen was placed over the background specimen. Finally the all-ceramic specimen was placed over these specimens in the manner that it's glazed surface would be the upper side. In order to provide a good optical contact, a drop of optical fluid (Optical Gel, Cedar Grove, NJ) was applied on to both background and cement specimens [30,33–35]. The second component and the

Table II. ΔL values between the test and the control groups.

ΔL	Cement colors		
Backgrounds	Translucent	Universal	White Opaque
Zirconium	−1.06 (0.66)^{Aa}	−0.46 (0.44)^{Aa}	−1.24 (1.02)^{Aa}
Gold-Palladium	1.92 (0.79)^{Ab}	1.90 (0.47)^{Ab}	1.52 (0.87)^{Ab}
Titanium	3.03 (0.65)^{Ac}	3.54 (0.74)^{Ac}	2.78 (0.71)^{Ac}

Results of statistical comparisons between background and cement color groups were shown as superscripts and values having the same letters are not significantly different for Tukey test ($p > 0.05$). Superscripts with capital letters show the differences between cement color groups and lower case letters show differences between background groups.

Table III. Δa values between the test and the control groups.

Δa	Cement colors		
Backgrounds	Translucent	Universal	White Opaque
Zirconium	−0.78 (0.26)^{Aa}	−0.81 (0.28)^{Aa}	−0.62 (0.29)^{Aa}
Gold-Palladium	−2.63 (0.62)^{Ab}	−2.06 (0.42)^{Bb}	−1.99 (0.40)^{Bb}
Titanium	0.13 (0.14)^{Ac}	−0.40 (0.86)^{Ac}	0.08 (0.35)^{Ac}

Results of statistical comparisons between background and cement color groups were shown as superscripts and values having the same letters are not significantly different for Tukey test ($p > 0.05$). Superscripts with capital letters show the differences between cement color groups and lower case letters show differences between background groups.

spectrophotometer were placed over the glazed surface of ceramic specimen then color measurements were repeated 3-times for this layer combination. The spectrophotometer recorded the measurements at the CIE (Commission International del'Eclairage) L*a*b* color space system which allows the determination of color in the three-dimensional space. The L* represents the value (lightness or darkness) co-ordinate and its ranges from 0 (black) to 100 (white). The a* b* are chromaticity co-ordinates and a* value is a measure of redness (positive a*) or greenness (negative a*). The b* value is a measure of yellowness (positive b*) or blueness (negative b*) [36–39].

When the color measurements finished for this layering combination, the translucent shade cement specimen was removed carefully and new measurements performed with universal and white opaque shade cement specimens with the same ceramic specimen. In this manner, color measurements for the first ceramic specimen with different colors of cement specimens were completed. This procedure was repeated for another nine ceramic and cement groups over the same background then also all measurements were repeated for other backgrounds too. ΔL, Δa and Δb values were calculated as the difference of the respective L*, a*, b* values of the test and control sites. Then the color difference (ΔE) between the average values of implant abutment material (backgrounds) and the A_2 background was determined using the following formula: $\Delta E = [(\Delta L^\star)^2 + (\Delta a^\star)^2 + (\Delta b^\star)^2]^{1/2}$. Several studies that perceptible color differences from 1–2 [33,36,37,40,41], but acceptable color differences for dental professionals ranged from 2.6–3.7 [42–44]. In this study; a ΔE value greater than 3 was considered to be visually perceptible as well as clinically not acceptable [45–47].

Color variation data were statistically analyzed. Firstly, the Shapiro-Wilk test was used for evaluating the normal distribution of the variables. The test showed normal distribution of the variables. Secondly, one-way ANOVA was performed to test whether there were any differences among the groups. Finally, means were separated by using Tukey's multiple comparison. Significance was evaluated at $p < 0.05$ for all tests. All the computational work was performed by means of SPSS 17.0 V statistical software (SPSS 17.0 V; SPSS Inc., Chicago, IL).

Results

The average ΔL, Δa, Δb and ΔE values and standard deviations of cement/background combinations are shown in Tables II III IV and Figures 1 and 2. In Table V and Figure 3, mean values of background and cement color groups were shown too. Statistical differences between the background and cement color groups were also shown in these tables as superscripts. Superscripts with capital letters show the differences between cement color groups and the lower case letters show differences between background groups.

In Table II, all-ceramic on a zirconium background appears whiter (negative ΔL values) while each cement color groups and titanium background caused a darker appearance between the abutment materials. The lowest ΔL value was gained for the zirconium background with the universal color cement group (ΔL = −0.46) and the highest was for the titanium background with the universal color cement group (ΔL = 3.54). There was a statistically significant difference between all backgrounds for each cement

Table IV. Δb values between the test and the control groups.

Δb	Cement colors		
Backgrounds	Translucent	Universal	White Opaque
Zirconium	−1.05 (0.89)^{Aa}	−1.47 (0.54)^{Aa}	−2.43 (0.83)^{Ba}
Gold-Palladium	−0.75 (0.62)^{Aa}	0.24 (0.86)^{Bb}	−2.25 (0.59)^{Ca}
Titanium	3.06 (0.69)^{Ab}	2.67 (0.83)^{Ac}	1.78 (0.52)^{Bb}

Results of statistical comparisons between background and cement color groups were shown as superscripts and values having the same letters are not significantly different for Tukey test ($p > 0.05$). Superscripts with capital letters show the differences between cement color groups and lower case letters show differences between background groups.

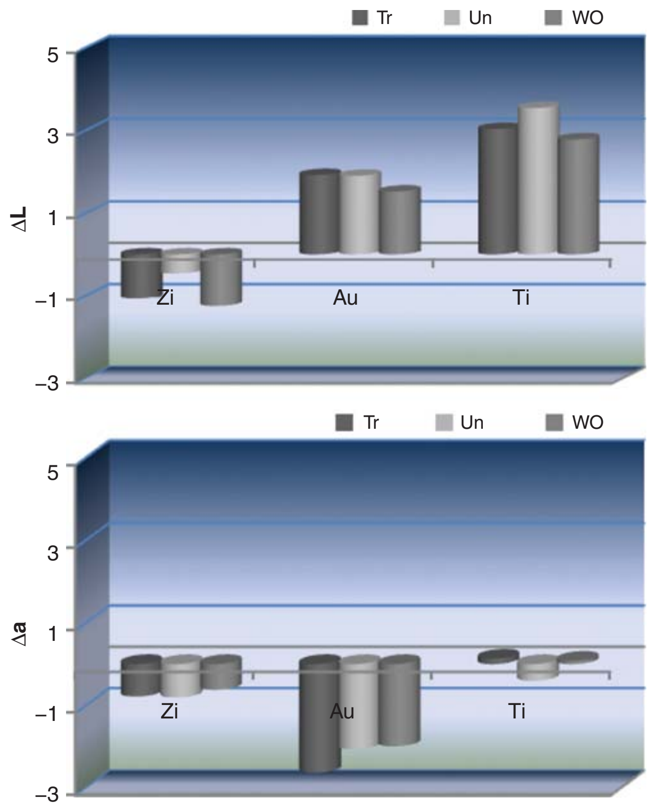

Figure 1. Mean ΔL, Δa values of background groups with different cement colors.

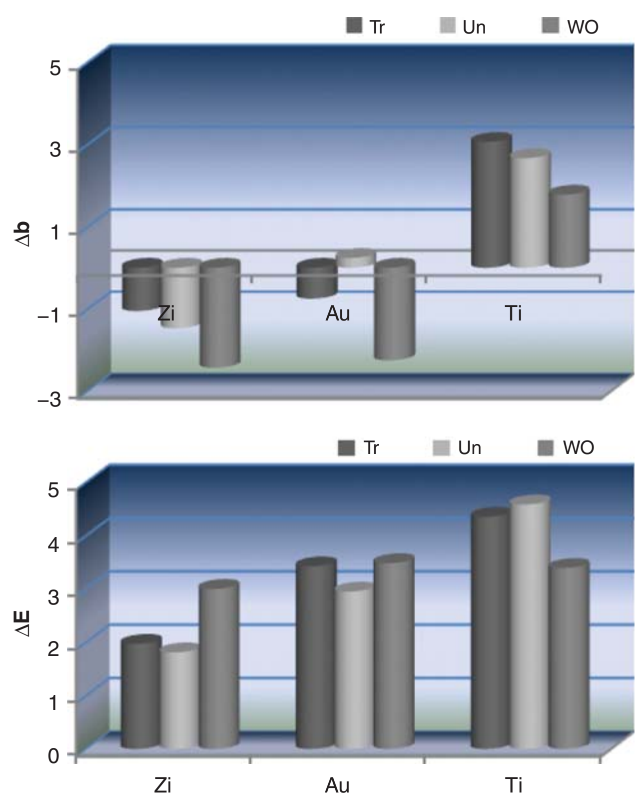

Figure 2. Mean Δb, ΔE values of background groups with different cement colors.

Table V. ΔE values between the test and the control groups.

ΔE	Cement colors			
Backgrounds	Translucent	Universal	White Opaque	Mean/Backgrounds
Zirconium	1.97 (0.38)^{Aa}	1.81 (0.55)^{Aa}	3.00 (0.70)^{Ba}	2.26 (0.76)^{x}
Gold-Palladium	3.42 (0.86)^{Ab}	2.95 (0.48)^{Ab}	3.48 (0.66)^{Aa}	3.29 (0.70)^{y}
Titanium	4.35 (0.67)^{Ac}	4.58 (0.65)^{Ac}	3.39 (0.45)^{Ba}	4.11 (0.78)^{z}
Mean/Cement	3.25 (11.9)^{X}	3.11 (1.28)^{X}	3.29 (0.63)^{X}	

Results of statistical comparisons between background and cement color groups were shown as superscripts and values having the same letters are not significantly different for Tukey test ($p > 0.05$).
Superscripts with capital letters show the differences between cement color groups and lower case letters show differences between background groups.

color group ($p \leq 0.05$), but no statistically significant differences were obtained between cement colors for all background groups ($p > 0.05$).

In Table III, all ceramics with a more green appearance (positive Δa value) were obtained only on a titanium background with the translucent, white opaque cement color groups. A gold-palladium background caused the most reddish appearance between the abutment materials. The lowest Δa value was gained for the titanium background with the white opaque color cement group (Δa = 0.08) and the highest was for the gold-palladium background with the translucent color cement group (Δa = −2.63). There was a statistically significant difference between all backgrounds for each cement color group ($p \leq 0.05$). There was also a statistically significant difference acquired between translucent and other cement colors for gold-palladium background groups ($p \leq 0.05$). However, there was no statistically significant difference obtained between cement colors for other background groups ($p > 0.05$).

In Table IV, all ceramics with blueish appearance (positive Δa value) were obtained on a titanium background with each cement color group and on a gold-palladium background with the universal cement color groups. The zirconium background caused a more yellowish appearance between the abutment materials. The lowest Δb value was gained for the gold-palladium background with the universal color cement group (Δb = 0.24) and the highest was for the titanium background with the translucent color cement group (Δb = 3.06). There was a statistically significant difference between all backgrounds for the universal and white opaque cement color groups and also between titanium and other backgrounds for the translucent cement color groups ($p \leq 0.05$). There was also a statistically significant difference acquired between each cement color for the gold-palladium background groups and between white opaque and other cement colors for the zirconium and titanium background groups ($p \leq 0.05$).

In Table V, only the ΔE value of the zirconium background group was at a clinically acceptable level (ΔE = 2.26), among the mean ΔE values for backgrounds and cement color groups. Among the study groups, the ΔE values of zirconium background with each cement color group and the gold-palladium with universal color cement group were at a clinically acceptable level (ΔE ≤ 3.00).

Among the mean cement color groups, the highest ΔE value was gained for white opaque (ΔE = 3.29) and the lowest for universal (ΔE = 3.11) color cement. Also, among the mean background groups, the highest ΔE value was gained for titanium (ΔE = 4.11) and the lowest for zirconium (ΔE = 2.26) backgrounds. There was a statistically significant difference between each mean background group ($p \leq 0.05$), but no statistically significant difference was obtained between the mean cement color groups ($p > 0.05$).

Among the study groups, the highest ΔE value was gained for the titanium background with the universal color cement group (ΔE = 4.58) and the lowest for the zirconium background with the universal color cement group (ΔE = 1.81). Generally, the titanium background caused the highest color change values for all ceramic and the zirconium background caused the lowest. Although the universal color cement groups exhibit the lowest ΔE value and white opaque exhibits the highest on zirconium and gold-palladium backgrounds, this result became reversed on a titanium background. There was a statistically significant difference between each background for

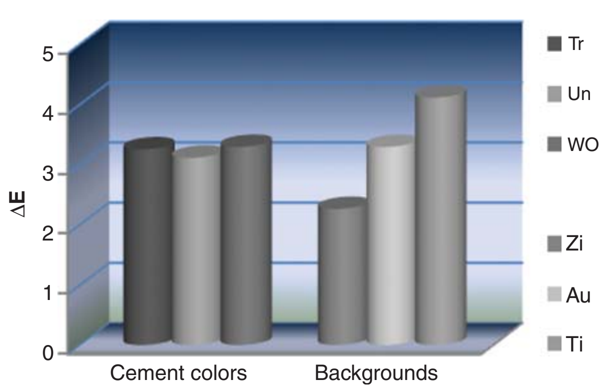

Figure 3. Mean ΔE values for backgrounds and cement color groups.

translucent and universal cement color groups ($p \leq 0.05$), but no statistically significant difference was obtained between backgrounds for the white opaque cement color groups ($p > 0.05$). There was a statistically significant difference between white opaque and other cement colors on zirconium and titanium background groups ($p \leq 0.05$), but no statistically significant difference was obtained between cement colors on gold-palladium background groups ($p > 0.05$).

Discussion

On the basis of these data, the hypotheses set as the premises of this study were accepted. The present study showed that all of the evaluated implant abutment materials affect the final color of lithium disilicate all-ceramic and there was a statically significant difference between their mean color change values. Also the luting cements colors affect the final colors of lithium disilicate all-ceramic, but there was no statically significant difference between their mean color change values.

According to the ΔL values, it can be claimed that using zirconium abutments results in a whiter appearance and gold-palladium and titanium abutments cause a darker appearance. This finding is well documented in the literature and may be explained by increased absorption, reduced transmission and reflection of incident light by dark metallic structure [16,18,30,48]. Also the dark grey color of titanium alloys further absorbs more incident light than the gold-palladium alloys yellowish grey color and, as a result, appear darker. However, zirconium allows slight light transmission and also its white color alters the reflection, which results in a whiter appearance. Cement color has no statistically significant difference on the ΔL values, but the white opaque cement color caused a whiter appearance for all background groups. This result is in line with the findings of Uzun and Keyf's [16] study, which indicated that white opaque cement could be used to mask the color of metallic abutments and increase the translucency of zirconium abutments.

Although there are many investigations about the clinically acceptable and visually perceptible level of ΔE value, only a few studies refer to such a level about Δa and Δb values. Douglas et al. [49] stated 1.1 and 2.1; and Lindsey et al. [50] 1.0 and 2.6 values for clinically acceptable levels of Δa and Δb in their studies Jalali et al. [30]. In this study; all Δa values of gold palladium background groups were greater than the clinically acceptable levels and appeared more reddish. Δb values of zirconium and gold palladium backgrounds with white opaque cement groups were greater than Douglas et al.'s [49] clinically acceptable level ($\Delta b > 2.1$) and appeared more yellowish. On the other hand, Δb values of titanium backgrounds with translucent and universal cement groups were greater than both investigators' clinically acceptable levels and appear bluer. In general, all-ceramic samples appeared more reddish and yellowish on the zirconium and gold palladium backgrounds, while the titanium background caused a more green and blue appearance. These results derived from the coloration show through from the gold palladium and titanium backgrounds. The background effect of gold and ceramics on the final color of ceramic crowns was previously investigated [18]. Greater a^* and b^* values of ceramic crowns with gold alloy background were reported as a result of red and yellow coloration of gold alloy. In the present study, the color of the gold-palladium alloy showed more influence on the a^* parameter of all ceramics and similarly the color of titanium influenced the b^* parameter.

To examine the effect of implant abutment colors, an A_2 composite resin background was used as a control to represent natural teeth as the experimental background [48]. Only the zirconium abutment background with all cements and gold-palladium background with the universal shade cement groups could exhibit a clinically acceptable color reproduction under all ceramic restorations ($\Delta E \leq 3.0$). However, when the mean ΔE values of the background groups were compared, both gold palladium and titanium background groups were clinically not acceptable ($\Delta E > 3.0$). Although the gold palladium abutments exhibited a better appearance compared to the titanium, the best esthetic result could be acquired by the use of zirconium abutments. It was suggested in similar studies that the color of Empress restorations was not affected by the metal abutment color, when the thickness of the restoration was more than 1.5 mm [17,18]. However, in contrast, our study showed that; 1.5 mm thick IPS e.max all-ceramic was not able to mask the metallic background color, especially with the titanium background.

Resin luting cements are used in order to: (1) improve mechanical properties through bonding the crown to the prepared tooth, (2) mask the underlying color and (3) modify the final restoration color [11]. Optical effects of luting cements on the final restoration color were evaluated in previous studies. Several of those studies showed that this effect was not significant [17,44]. Whereas several others suggested that the color of the luting cement exhibited a significant effect on the final color of translucent restorative materials [11,21,30,31,51], in the current investigation there was no statistically significant difference determined between mean ΔE values of cement color groups. However, when the cement colors were compared over different background sub-groups, a statistically significant difference was found between white opaque and the other cement color groups for zirconium and titanium backgrounds. While white opaque cement has significantly increased the ΔE value of the zirconium background, it also decreased the ΔE value of the titanium background. This indicates that white opaque cement might be helpful to mask the dark reflection (color) of the titanium abutment. It was indicated in a previous study that using opaque or bleach shade luting cements had been shown to lighten the color of a crown placed on a darker substrate [11]. Additionally, similar ΔE values of different backgrounds with white opaque cement groups indicate the masking ability of 0.2 mm thick white opaque luting cement.

Conclusion

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

(1) Only the zirconium implant abutment groups and the gold palladium abutment with universal shade cement group were found to be clinically acceptable ($\Delta E \leq 3.0$). Using titanium abutments or gold palladium abutments with other shade cements for lithium disilicate, all-ceramic restorations will be easily visually perceptible and clinically not acceptable.

(2) When zirconium is preferred as an implant abutment material, translucent and universal shade cements exhibit a more esthetic appearance than white opaque cement. Conversely, titanium implant abutments appear more esthetic with white opaque cement than the others. However, even the white opaque cement was not able to mask the color of the titanium background under the clinically acceptable parameter ($\Delta E \leq 3.0$).

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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