The Effect of Screw Color and Technique to Fill Access Hole on the Final Color of Screw-Retained Implant Crowns

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The purpose of this study was to investigate the effect of screw color and thickness of the composite on the final implant color. Gray and golden-colored titanium specimens were used as 2 different backgrounds. Composite disks were made in different thicknesses. Titanium and composite disk samples were placed into a metal mold as in the test groups for color measurement. The background color did not affect the final color. Composite resin thickness affected the final color.

Key Words: access hole, dental implant, composite, opaque, masking, color

INTRODUCTION

The demand for esthetically pleasing results emphasizes the importance of naturally colored and shaped restorations that harmonize imperceptibly with the surrounding natural tooth structure. However, the patient's expectation of primary importance is a healthy functional dentition along with an aesthetic smile. It has been reported that in the United Kingdom, 28% of people are dissatisfied with the appearance of their teeth, and in the United States, 38% are dissatisfied with their tooth color.

In implant-supported prosthetic treatments, selection of restorative components and of the connection system between implants and restorations must be considered a paramount factor for long-term success. The implant systems available today offer different types of connections between prosthetic restorations and supporting implants. Some authors suggest that cement-retained restorations should be used; others have considered screw-retained prostheses as the best choice for a long time.

Screw-retained prostheses offer the advantage of retrievability, the simplicity of replacement, and the maintenance of both restorations and implants, making evaluation of oral hygiene and peri-implant probing easier. Nevertheless, screw-retained prostheses cannot provide as good an aesthetic result as cement-retained prostheses because of the presence of the
occlusal access hole. If screw retention is used, the access hole must be filled to help ensure the success of the implant restoration; however, many times, the esthetics of the restoration is compromised to maintain its functionality.\textsuperscript{16,17}

The color of the filling materials used for restoration of the access hole may exhibit disparities due to usage, location, and thickness. Most dental materials are relatively translucent and are unable to completely mask the dark, underlying metal oxide layer lining the access hole.\textsuperscript{17,18} A black background color can affect the lightness of the materials and may cause chromatic changes.\textsuperscript{1,19} In such situations, composite resin restorations can result in a grayish shade or a poor color match because the translucent materials are affected by the discolored tooth structure or the darkness of the oral cavity and the access hole of the abutment of the implant.\textsuperscript{20} Translucency is also affected by the thickness of the composite resins.\textsuperscript{1,21} The background affects the overall shade of a composite resin, even at a thickness of 2 mm,\textsuperscript{2,22,23} while the light-absorbing and internal-reflecting properties of the composite alter the amount of background effect.\textsuperscript{19}

The color of the titanium screw of the screw-retained abutment is commonly gray. Coloring of titanium can be achieved through several techniques, with electrolytic oxidation (anodizing) most commonly used in the industry.\textsuperscript{24} Anodic oxidation is an electrochemical treatment method that can control the thickness of an oxide layer formed on a titanium surface; it offers the advantage that it can be readily applied to materials with complex surface patterns such as implant fixtures. The phenomenon of voltage-controlled oxide thickness indicates that the color is also voltage controlled. As the voltage increases, the thickness of the layer also increases. Certain colors will appear at specific voltage levels.\textsuperscript{25}

The color of the underlying material may affect the color of the restorative materials. So it may be possible that the color difference of the screws may also affect the final color of the restorations. Color measurements are made visually and instrumentally. However, the visual system of the eye is capable of detecting only wavelengths from 380 (violet) to 780 nm (red).\textsuperscript{26} Instrumental methods became very popular in dental research because of the development of new technologies that are user friendly and offer objective information on color specification, as well as on the magnitude and direction of color differences.\textsuperscript{27}

Color change ($\Delta E$) mathematically expresses the amount of difference between the Commission Internationale de l’Eclairage (CIE) $L^*a^*b^*$ coordinates of different specimens and the same specimen at different instances.\textsuperscript{28,29} The $L^*$ value is a measure of lightness, the $a^*$ value is a measure of redness (positive $a^*$) or greenness (negative $a^*$), and the $b^*$ value is the measure of yellowness (positive $b^*$) or blueness (negative $b^*$) of an object.\textsuperscript{30} The human eye has limited capability to perceive color differences. It cannot perceive $\Delta E$ values less than 1.\textsuperscript{31,32} Delta $E$ values between 1 and 3.3 represent a perceptible and clinically acceptable range. Delta $E$ values of 3.3 and higher are reported to be unacceptable under clinical conditions.\textsuperscript{33} A $\Delta E$ value of 3.3 has been used as the upper limit in several studies exploring the perceptibility of color differences.\textsuperscript{34,35}

No published report has described evaluating the screw color of the occlusal screw-retained implant restoration and filling technique of the access hole by instrumental measurement. The aim of this study was to investigate whether screw color had an effect on the final color of the restoration, and whether this was affected by the thickness of composite resin and opaque shade composite usage. Our research hy-
Hypothesis is that opaque shade composite usage, composite thickness, and the color of the background (gray and golden-colored titanium) would affect ΔE values of the final color of the restoration.

**Materials and Methods**

**Background preparation**

Titanium bars of commercially pure titanium (grade 2; Bağsan Bağlanti Elemenları Tic. A.Ş., Istanbul, Turkey) were sectioned with a lathe (Hawk TC-150; Cincinnati Machine Ltd, London, UK) into 80 specimens, 2 mm in length and 10 mm in diameter (Figure 1B). Forty specimens were anodized in 165 g/L sulfuric acid at 23°C for 5 minutes by applying 55 voltage to obtain a golden color (Bahadir Tibbi Aletler A.Ş., Samsun, Turkey). Thirty-six gray titanium and 40 golden-colored titanium specimens were used as 2 different backgrounds in the study.

**Specimen preparation**

Light curing hybrid composites A2 and OA2 (Quadrant Universal LC, Cavex, Holland) were used in this study (Figure 1B). Composite disks were made by condensing each composite into a custom-designed Teflon mold 10 mm in diameter with one of the following thicknesses: 0.5 mm, 1 mm, 1.5 mm, and 2.0 mm (±0.10 mm). The composite resin was pressed between glass plates to achieve flat, smooth surfaces, and both surfaces were polymerized for 40 seconds at a distance of 1 mm, using a light source (Astralis 3, light intensity of 600 mW/cm²; Ivoclar-Vivadent, Schaan, Liechtenstein), according to the manufacturer's instructions. The specimens were wet ground with 1000 grit silicon carbide abrasive paper for 10 seconds on a 300-rpm grinding machine (Buehler Metaserv, Buehler, Germany), then were stored in distilled water at 37°C for 24 hours. Test groups were generated as follows (Figure 2):

- Group Gr1: gray titanium + 1 mm composite resin
- Group Gr2: gray titanium + 2 mm composite resin
- Group GrO1: gray titanium + 0.5 mm opaque + 0.5 mm composite resin
- Group GrO2: gray titanium + 0.5 mm opaque + 1.5 mm composite resin
- Group G1: golden-colored titanium + 1 mm composite resin
- Group G2: golden-colored titanium + 2 mm composite resin
- Group GO1: golden-colored titanium + 0.5 mm opaque + 0.5 mm composite resin
- Group GO2: golden-colored titanium + 0.5 mm opaque + 1.5 mm composite resin

**Color measurements**

Two custom-made cylindrical nickel chrome metal molds with a hole in the center (11 mm
in diameter, 3 and 4 mm in thickness) were casted to simulate the access hole of the metal framework of a screw-retained implant restoration (Figure 1A). Titanium and composite disk samples were placed into the metal mold as in the test groups for color measurement (Figure 3).

Optical contact was achieved by using an optical fluid (refractive index = 1.5) between the composite resin samples and the titanium backgrounds.

Color measurements were made with an intraoral dental spectrophotometer (Easy Shade; VITA Zahnfabrik H, Bad Säckingen, Germany). The spectrophotometer was calibrated before each measurement period using a white calibrating sample supplied by the manufacturer, and 3 measurements were done for each specimen.

ΔE values for each group were calculated as follows:

\[ ΔE = (L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2 \]

L₁ represents the value obtained from experimental specimens.
L₀ represents the value obtained from control specimens. One and two millimeter composite resins were prepared and served as a control, and color measurements were made with a white background.

Mean ΔE values were evaluated for normal distribution with the Kolmogorov-Smirnov test. Because data were not normally disturbed (P < .05), Kruskal-Wallis analysis of variance was applied to assess significant differences among the experimental groups (α = .05). The nonparametric Mann-Whitney U test was applied for post hoc comparisons (P < .05). Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS), version 12.0 (SPSS Inc, Chicago, Ill).

**Results**

To evaluate the effect of background color and thickness of the composite resin, opaque shade composite resin nonparametric analyses were performed using the Kruskal-Wallis test, and for pairwise comparisons, the Mann-Whitney U test was used. The color of the background was not an effective factor for determining final color (P = .266, Z = −1.111). Observed differences in mean ΔE values between the tested groups depended on the thickness of composite resin (P < .05, Z = −6.365) and the use of opaque shade composite resin (P < .05, Z = −4.903), indicating severe interactions among these variables (P < .05). The mean and the standard deviation of ΔE values are listed in the Table.

The lowest ΔE values were obtained in the group G02, and no significant difference was noted between groups GO2 and GrO2. The highest ΔE values were obtained in the group G1, and no significant difference was observed between groups G1 and Gr1.

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**TABLE**

Mean and standard deviation of ΔE values of the groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Test Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr1</td>
<td>9.5 ± 0.76 A</td>
</tr>
<tr>
<td>G1</td>
<td>9.7 ± 1.0 A</td>
</tr>
<tr>
<td>Gr01</td>
<td>4.9 ± 1.3 B</td>
</tr>
<tr>
<td>GO1</td>
<td>5.6 ± 1.3 B</td>
</tr>
<tr>
<td>Gr2</td>
<td>4.0 ± 0.7 C</td>
</tr>
<tr>
<td>G2</td>
<td>4.5 ± 0.5 C</td>
</tr>
<tr>
<td>Gr02</td>
<td>2.7 ± 0.5 D</td>
</tr>
<tr>
<td>GO2</td>
<td>2.6 ± 0.7 D</td>
</tr>
</tbody>
</table>

*Values having same letters (upper case: within background) were not significantly different for the Mann-Whitney U test (P > .05).
Results showed that composite resin thickness and opaque composite application affected the ΔE values \((P < .05)\). ΔE values decreased as composite thickness increased. GO2 and GrO2 groups showed lower ΔE values than the clinically acceptable limit of 3.3. The color of the background (gray and golden-colored titanium) did not affect ΔE values \((P > .05)\).

**DISCUSSION**

In this research, our hypothesis was partially accepted. Composite thickness and opaque shade composite usage affected ΔE values \((P < .05)\); however, the color of the background (gray and golden-colored titanium) did not affect ΔE values \((P > .05)\).

In a previous study, the authors stated that because the actual thickness of restorations and the corresponding specimen for color measurements are usually 1–2 mm, the effect of background on the color of esthetic materials would be significant. Unless material thickness is adequate, about 1 to 1.5 mm, the opacity may be insufficient, thereby marring the final color result of the restoration. The background color is known to affect the overall shade of a composite resin, even at a thickness of 2 mm.

Examination of the literature on dental color measurement reveals that some did not identify the background, and others used varied backgrounds. Some studies reported that the color of composite resins is affected by the background environment. Some amount of incident light transmits through the material and reaches the eye of the observer. In this case, the transmitted light with the optical or color information of the background and the surrounding environment will affect the appearance of the resin.

Kourtis et al stated that the type of the alloy substrate significantly affected the color. Gold (Au) and cobalt-chrome (Co-Cr) alloys were found to be brighter than nickel-chrome (Ni-Cr) and palladium (Pd) alloys. As was previously mentioned, the alloys with a high gold content have been considered as a reference point for color reproduction. For this purpose, in the present study, standard gray titanium backgrounds were compared with golden-colored titanium backgrounds.

A previous study evaluating the translucency of opaque shade resin composite (1 mm and 2 mm thickness) indicated that opaque shade resin composites were less translucent than the usual composites, and if a restoration was relatively thin, the opaque shade resin composites could not mask the dark background color as well as the usual composites.

However, Kim et al evaluated the masking ability of various thicknesses of opaque shade composite on C4 shade backing and black backing; they indicated that ΔE values decreased when the thickness of opaque shade resin composites increased. In our study, the use of 0.5 mm thick opaque shade composite resin affected the final color of the specimens \((P < .05)\). This result is consistent with the previous findings of Kim et al. Lowest ΔE values were obtained in the GO2 and GRO2 groups. This can be attributed to opaque shade composite usage. Weininger et al showed that usage of an opaquer underneath the composites diminished the translucency of composites; they reported that a remarkable improvement was noted in both esthetic value and acceptability when an opaquer was used. In another study, Felippe et al reported that opaquers provide efficacy to mask the background.

Although the Gr2 and G2 groups showed higher ΔE values than the clinically acceptable limit of 3.3, these test groups showed lower test values than groups G1 and Gr1. This result showed that the composite
thickness affected $\Delta E$ values. With parallel results in our research, Jarad et al. reported that thickness affected the color and shade of composite resin. In this study, researchers showed that increased thickness produces a more esthetically pleasing result. The optical characteristics of composite resins are dependent on the type and size of filler particle and the pigment of the resin. Filler particles absorb and scatter light because of their refractive and reflective properties and thus alter the transmission spectrum. Background color has long been known to affect the overall color of a composite resin. Thin composites contain fewer filler particles; therefore, more background light is reflected, increasing the impact of the background shade.

Lee et al. stated that the background influenced the (CIE) $L^*a^*b^*$ values differently when they used 2 mm cured and uncured resin composites as different backgrounds. In contrast to the findings of Lee et al., in this research, no significant differences were found between the G1 and Gr1 groups or between the GrO2 and GO2 groups. According to these test results, background titanium color did not affect $\Delta E$ values. This result may be related to usage of opaque shade composite. The literature shows that to minimize the effect of background color opaque shade, composite resins have been utilized as a backing by using a layering technique; with this method, the translucency of composite resin is as critical as the color of the materials.

One of the indications of occlusal screw-retained implant restorations is limited interocclusal distance. For this purpose, a total of 2 mm filling material thickness was evaluated in this study.

The use of a cotton pellet over the screw, because it was a white opaque color, could affect the color of the composite during attempts to match the porcelain shade of the restoration. Cotton pellet was not used in the present study because it was difficult to standardize the thickness of cotton pellets. Using different shades of composite is known to produce different esthetic results. The optical characteristics of composite resins are dependent on the type and size of filler particles and on the pigment of the resin. Use of only one type of composite resin material and disuse of cotton pellet may be limitations in this in vitro study.

**CONCLUSIONS**

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

1. The color of the background (gray and golden-colored titanium) did not affect the final restoration color.
2. When the thickness of composite resin was increased and opaque shade composite resin was used under the composite resin, masking the color of the background was more effective.

**ABBREVIATION**

CIE: Commission Internationale de l’Eclairage

**ACKNOWLEDGMENT**

The authors thank Bahadir Tibbi Aletler, A.Ş., Turkey, for preparing titanium test specimens.

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