A Clinical Study Assessing the Influence of Anodized Titanium and Zirconium Dioxide Abutments and Peri-implant Soft Tissue Thickness on the Optical Outcome of Implant-Supported Lithium Disilicate Single Crowns

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Purpose: To assess the influence of anodized titanium and zirconium dioxide abutments and peri-implant soft tissue thickness on the optical outcome of implant-supported lithium disilicate single crowns. Materials and Methods: Twenty patients with a missing maxillary single incisor, canine, or first premolar received an endosseous implant after a two-stage surgery protocol. After healing and soft tissue conditioning, peri-implant soft tissues were reproduced in the impression, and the thickness was measured. Customized abutments were made of titanium, gold-anodized titanium, pink-anodized titanium, and zirconium dioxide. The definitive prosthesis was a lithium disilicate crown stratified by feldspathic porcelain. Customized abutments were screwed (35 Ncm), and the crown was temporarily placed on the abutment with a try-in paste. Color measurements were made using a spectrophotometer. CIELab color scale was employed following the formula: \( \Delta E = (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2 \). Data were analyzed using repeated-measures analysis of variance (ANOVA), Bonferroni and Pearson’s correlation tests (\( \alpha = .05 \)). Results: Abutment material type significantly affected the \( \Delta E \) values at both the peri-implant soft tissue (\( P = .0001 \)) and coronal level (\( P = .001 \)). The lowest \( \Delta E \) values were obtained with zirconia abutments at both soft tissue (6.06 ± 3.2) and coronal level (5.76 ± 2.9) compared with those of other abutments (soft tissue: 8.96 ± 3.1 to 11.56 ± 3.4; coronal: 8.66 ± 6.1 to 10.42 ± 6.3). Mean soft tissue thickness (1.63 ± 0.64 mm) affected the \( \Delta E \) values at the peri-implant soft tissue level for only titanium and pink-anodized titanium abutments (\( P = .024 \) and \( P = .048 \), respectively). In all conditions, correlation coefficients between \( \Delta E \) and the abutment materials were higher for titanium (\( r = −0.544; P = .024 \)) and the least for zirconia (\( r = −0.313; P = .238 \)) and gold-anodized titanium (\( r = −0.393; P = .119 \)) abutments. Conclusion: All abutment types demonstrated noticeable color difference at both the soft tissue and coronal levels. Zirconia abutments showed the lowest \( \Delta E \) values at both measurement zones. Soft tissue thickness did not affect the \( \Delta E \) values at the peri-implant soft tissue level. INT J ORAL MAXILLOFAC IMPLANTS 2017;32:156–163. doi: 10.11607/jomi.5258

Keywords: color, implant abutments, lithium disilicate, oral implants, soft tissue, spectrophotometer, titanium, zirconia

The use of dental implants to restore function and esthetics following the loss of a single tooth is well documented with high implant survival and success rates.1,2 Yet, the visual outcome is not always predictable especially in esthetically sensitive areas, and therefore, this has become one focus of research interest in recent years.3 Successful esthetic rehabilitation in implant dentistry is dictated by a number of factors that involves the position, inclination, shape, and color of the implant, components of implant systems, and the material type used for the fabrication of the fixed dental prosthesis (FDP).4 Several studies have proposed the use of all-ceramic crowns for esthetic rehabilitation of single-tooth implants, with survival rates varying between 87% and 97% after 5 years.5–7

The quality, structure, thickness, and color of the soft tissues around the implant-supported FDPs may also dictate achieving appropriate esthetic results.3 In that respect, utilization of customized abutments...
with different emergence profiles is crucial in order to mimic the appearance of natural teeth. Custom-made implant abutments are usually fabricated from grade 5 titanium alloys due to their well-documented biocompatibility and mechanical properties. However, their metallic color may still shine through the mucosa, impairing the optical outcome. Even when placed subgingivally, a dull gray shine through may give the soft tissue an unnatural appearance. The presence of a gray gingival discoloration may also be partially attributed to a thin peri-implant tissue thickness around the abutment that is not capable of hindering the reflective light from the metal abutment surface.8,9 Hence, although they are very stable from the biomechanical point of view, titanium abutments have limitations in esthetically delicate areas.

On the reconstruction level, metal abutments may also influence the final outcome of highly translucent all-ceramic FDPs cemented on such abutments. Consequently, the use of all-ceramic abutments made of lithium disilicate or yttrium-stabilized tetragonal zirconia polycrystals (Y-TZP; hereon: zirconia) have been suggested in an effort to overcome this esthetic problem.10 Nevertheless, in vitro studies have shown that fracture resistance of all-ceramic crowns on titanium abutments were higher than those on ceramic abutments.11–14 In addition, environmental stresses could alter the metastable tetragonal crystalline phase of zirconia.15 Thus, in that respect, titanium abutments could still be considered mechanically more reliable compared with zirconia when exposed to long-term clinical function.15 Moreover, tattooing in the gingival tissues related to the use of zirconia abutments could also occur as a consequence of titanium implant wear that is connected to the zirconia abutment. Thus, using a secondary titanium insert might be useful in preserving the stability of zirconia abutments.16

Considering the advantages and disadvantages of both titanium and ceramic abutments used in conjunction with computer-aided design/computer-assisted manufacture (CAD/CAM) technologies, alternative coating methods for the custom-made titanium abutments have been suggested in an attempt to improve the optical properties of titanium.17 One such method is anodization of alloys. Anodization is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metals in the range of 30 to 150 nm.18 This method can generate pink or gold-shaded tones without the use of dyes that may eventually mask the metallic color of titanium abutments in the anterior region. Other methods described in the literature to solve this problem are the use of veneered metallic abutments to generate an acceptable dentin color or the use of titanium abutments with a thin coating of biocompatible titanium nitride, which provides a warm gold-shaded tone similar to anodization.19 While the veneering process with glassy matrix ceramic may add to the thickness of the abutment, leaving less space for the crown thickness, titanium nitride coating that is in the range of 1 to 5 microns may not be durable in oral conditions.18

The Commission Internationale de l’Eclairage L*, a*, and b* (CIELab) system permits quantitative evaluation of color.20 Clinical studies benefitted from assessing and reporting CIELab color coordinates. Typically, such coordinates are obtained from spectral reflectance measurements using a spectrophotometer through which numerical values are obtained in the three-dimensional color space. While the L* color coordinate (0 to 100) represents lightness, the a* color coordinate (–90 to 70) represents greenness on the positive axis and redness on the negative. The b* color coordinate (–80 to 100), on the other hand, represents yellowness (positive b*) and blueness (negative b*).

The color difference (∆E) expressed in L*, a*, and b* is then calculated using the following formula: ∆E = [(ΔL)2 + (Δa)2 + (Δb)2]1/2. ∆E units of 2 to 3 are considered perceptible, and a difference of less than 2 units is considered imperceptible.23,24 Other studies reported ∆E values greater than 3.7 units indicating mismatch, and ∆E values greater than 6.8 units signifying poor color matching.25–28

Therefore, the objectives of this clinical study were to evaluate the optical outcome of implant-supported lithium disilicate single crowns as a function of peri-implant soft tissue thickness and abutment type using intraoral spectrophotometric analysis. The tested null hypotheses were that neither the peri-implant soft tissue thickness nor the abutment material type would affect the optical outcome of all-ceramic crowns.

MATERIALS AND METHODS

Study Design and Patient Selection

This study was designed as a prospective randomized controlled clinical trial. The local ethical committee (University Complutense of Madrid, Madrid, Spain, No:11/383-E) approved all procedures and materials to be used, and all patients were provided with informed consent to participate in the study. Between May 2013 and June 2014, 20 patients aged between 24 and 69 years (11 women, 9 men, mean age: 53.4 years) in need of replacement of a maxillary single incisor, canine, or first premolar were recruited in the study (Fig 1a). The inclusion and exclusion criteria are listed in Table 1.

Surgical Procedures

Surgical interventions were performed under local anesthesia following a standard two-stage protocol. Each

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Three weeks after surgical reentry, an implant-level impression was made using polyvinylsiloxane (Virtual, Ivoclar Vivadent) for the fabrication of a machined screw-retained provisional restoration (Telio CAD, Ivoclar Vivadent) (Fig 1c). After 8 weeks of soft tissue conditioning by means of the provisional restoration, a definitive implant-level impression was made using polyvinylsiloxane (Virtual). A square transfer coping was customized by adding a self-polymerizing resin (Duralay) (Fig 1d). The peri-implant soft tissue was then reproduced in the impression using the polyvinylsiloxane gingival mask (Gingifast Rigid, Zhermack), and the master cast was poured in Type IV dental stone (Fujirock EP, GC) in accordance with the manufacturers’ instructions. Since the emergence profile was exactly replicated in the definitive model, the thickness of the vestibular peri-implant soft tissue was measured using a calliper on the model.

Customized abutments were made of titanium, gold-anodized titanium, pink-anodized titanium, and zirconium dioxide (Figs 2a to 2d), and the definitive prosthesis was an all-ceramic crown made of lithium disilicate framework (IPS e.max CAD, Medium Opacity, Ivoclar Vivadent) veneered manually using a fluorapatite veneering ceramic (IPS e.max Ceram, Ivoclar Vivadent). CAD/CAM technology was used to create the same morphology for the four types of abutments (Core Custom Abutments; Core3dcentres). While the vestibular and interproximal margin level was kept 1-mm subgingivally, the palatal margin was left at the gingival level. The internal connection of zirconia abutments was obtained using a secondary metallic component. Zirconia coping fabricated using CAD/CAM was bonded to the secondary titanium implant insert (Biomimetic Ocean HI Ti-Base, Avinent) using a resin luting agent (Panavia F2.0, Kuraray). The bonding surfaces of the titanium insert and the zirconia coping were air-abraded with 50-µm aluminum oxide particles at 2 bar pressure for 20 seconds from a distance of 10 mm. They were then cleaned with alcohol. Finally, zirconia abutment was cemented following the instructions of the manufacturer. Excess resin was removed from the bonded margins using microbrushes prior to polymerization.
At the beginning of each session and prior to data acquisition, the instrument was calibrated using a calibration plate, according to the manufacturer’s recommendation. The selected areas were standardized 3 mm in diameter over the middle third of the vestibular surface and at the gingiva 1 mm apical to the free gingival margin of the selected tooth or crown. Each selected area was measured three times. Color change (∆E) was recorded through CIELab color scale.

After all measurements, two operators and the patient further evaluated the esthetic outcome, and the best solution was delivered to the patient as the definitive reconstruction. The selected abutment was torqued down to 35 Ncm with a torque wrench, and the definitive all-ceramic crown was cemented using adhesive resin cement (Multilink Implant, Ivoclar Vivadent) according to the manufacturer’s instructions.

**Spectrophotometric Assessment**

Four weeks after the definitive implant-level impression, the provisional restoration was removed and customized abutments were screwed. The final all-ceramic crown was temporarily placed on the abutment with a try-in paste (Variolink Trial Base, Ivoclar Vivadent). Excess paste was cleaned with a sable brush (Kolinsky brush Ref. 17131004; Renfert). Each type of abutment was left in the mouth for 10 minutes, with the corresponding crown in position, before proceeding with the color measurement. Immediately after the first color measurement, the crown was removed, the first abutment was unscrewed, and the next abutment was positioned in the same manner as the first one. The sequence of choice of the type of abutment was randomly selected for each case. The measurement of the contralateral tooth (control site) was also performed to obtain a standard reference measurement.

One calibrated operator made the color measurements using an intraoral spectrophotometer (SpectroShade, Medical High Technologies) (Figs 3a to 3c). At the beginning of each session and prior to data acquisition, the instrument was calibrated using a calibration plate, according to the manufacturer’s recommendation. The selected areas were standardized 3 mm in diameter over the middle third of the vestibular surface and at the gingiva 1 mm apical to the free gingival margin of the selected tooth or crown. Each selected area was measured three times. Color change (∆E) was recorded through CIELab color scale.

After all measurements, two operators and the patient further evaluated the esthetic outcome, and the best solution was delivered to the patient as the definitive reconstruction. The selected abutment was torqued down to 35 Ncm with a torque wrench, and the definitive all-ceramic crown was cemented using adhesive resin cement (Multilink Implant, Ivoclar Vivadent) according to the manufacturer’s instructions.

**Statistical Analysis**

Statistical analysis was performed using the software SPSS 19.0 for Windows (IBM). Mean values and
Abutment material type significantly affected the ∆E values at both the peri-implant soft tissue ($P = .0001$) and coronal levels ($P = .001$) (Table 4). The data from spectrophotometry analysis are presented in Table 5. The lowest ∆E values were obtained with zirconia abutments at both the soft tissue ($6.06 \pm 3.2$) and coronal levels ($5.76 \pm 2.9$) compared with those of other abutments (soft tissue: $8.96 \pm 3.1$ to $11.56 \pm 3.4$; coronal: $8.66 \pm 6.1$ to $10.42 \pm 6.3$) (Table 6). Correlation coefficients between ∆E and tissue thickness were significant for the titanium ($r = –0.544; P = .024$) and pink-anodized titanium ($r = –0.486; P = .048$) abutments. The lowest correlations were observed with zirconia ($r = –0.313; P = .238$) and gold-anodized titanium ($r = –0.393; P = .119$) abutments (Table 7).

Table 4 Results of One-Way ANOVA with Repeated Measures at Peri-implant Soft Tissue Level and at Coronal Level ($\alpha = .05$)

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abutment type (peri-implant soft tissue level)</td>
<td>3</td>
<td>282.215</td>
<td>94.072</td>
<td>15.843</td>
<td>.0001*</td>
</tr>
<tr>
<td>Abutment type (coronal level)</td>
<td>3</td>
<td>186.143</td>
<td>62.048</td>
<td>6.343</td>
<td>.001*</td>
</tr>
</tbody>
</table>

ANOVA = analysis of variance.
*Statistically significant.

RESULTS

In the overall patient population, four implants replaced maxillary central incisors, five lateral incisors, four canines, and seven first premolars. Neither biological nor technical complications occurred during the observation period.

The mean soft tissue thickness was $1.63 \pm 0.64$ mm. Seventeen patients presented “thin” ($\leq 2$ mm) and the other three patients “thick” ($> 2$ mm) peri-implant soft tissues (Table 3).

Abutment material type significantly affected the ∆E values at both the peri-implant soft tissue ($P = .0001$) and coronal levels ($P = .001$) (Table 4).

The data from spectrophotometry analysis are presented in Table 5. The lowest ∆E values were obtained with zirconia abutments at both the soft tissue ($6.06 \pm 3.2$) and coronal levels ($5.76 \pm 2.9$) compared with those of other abutments (soft tissue: $8.96 \pm 3.1$ to $11.56 \pm 3.4$; coronal: $8.66 \pm 6.1$ to $10.42 \pm 6.3$) (Table 6). Correlation coefficients between ∆E and tissue thickness were significant for the titanium ($r = –0.544; P = .024$) and pink-anodized titanium ($r = –0.486; P = .048$) abutments. The lowest correlations were observed with zirconia ($r = –0.313; P = .238$) and gold-anodized titanium ($r = –0.393; P = .119$) abutments (Table 7).

DISCUSSION

This clinical study was undertaken to evaluate whether the optical outcome of implant-supported lithium disilicate single crowns could be affected in relation to the peri-implant soft tissue thickness (thin group: $\leq 2$ mm, thick group: $> 2$ mm) and the abutment type (titanium group, gold-anodized titanium group, pink-anodized titanium group, zirconia group) using intraoral
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One solution could be to increase the sintering temperature to decrease the contrast ratio, but then the grain size of zirconia increases, resulting in enhanced crack formation due to migration of yttrium to the grain boundaries. Thus, a compromise has to be made for the optical and mechanical properties where the sintering temperature should not exceed 1,550°C. On the other hand, with both gold and pink-anodized titanium, the mean ∆E values were almost twofold higher (soft tissue: 8.96 ± 3.1 to 11.56 ± 3.4; coronal: 8.66 ± 6.1 to 10.42 ± 6.3) compared with zirconia. Interestingly, however, gold-anodized titanium presented more favorable results compared to zirconia abutments at both the soft tissue and coronal level. In contrast to glassy matrix ceramics, zirconia as a ceramic material represents a more opaque ceramic type. In all-ceramics used for dental reconstructions, the translucency is affected by the thickness of the reconstruction and the crystalline content, where sintering parameters have an effect on the crystalline amount, affecting their translucency. The contrast ratio of zirconia, in particular, decreases from 0.85 to 0.68 with the increase in sintering temperature from 1,300°C to 1,700°C. The zirconia material used in this study as an abutment was sintered at 1,450°C. The mean ∆E values obtained with zirconia abutments at both the soft tissue (6.06 ± 3.2) and coronal levels (5.76 ± 2.9) were still high above the noticeable ∆E value, which is generally accepted to be more than 3 units. One solution could be to increase the sintering temperature to decrease the contrast ratio, but then the grain size of zirconia increases, resulting in enhanced crack formation due to migration of yttrium to the grain boundaries. Thus, a compromise has to be made for the optical and mechanical properties where the sintering temperature should not exceed 1,550°C. On the other hand, with both gold and pink-anodized titanium, the mean ∆E values were almost twofold higher (soft tissue: 8.96 ± 3.1 to 11.56 ± 3.4; coronal: 8.66 ± 6.1 to 10.42 ± 6.3) compared with zirconia. Interestingly, however, gold-anodized titanium presented more favorable results compared

### Table 5: Mean, SD, Range, and Confidence Interval Levels (95%) for ∆E Results Based on Abutment Type and Measurement Location

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Peri-implant</td>
<td>Coronal level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>soft tissue</td>
<td>Coronal level</td>
</tr>
<tr>
<td>Titanium abutment</td>
<td>11.56 ± 3.4</td>
<td>5.79–16.42</td>
<td>9.716–16.42</td>
</tr>
<tr>
<td>Gold-anodized titanium abutment</td>
<td>8.96 ± 3.1</td>
<td>4.86–14.87</td>
<td>7.306–14.87</td>
</tr>
<tr>
<td>Pink-anodized titanium abutment</td>
<td>10.68 ± 4.2</td>
<td>4.27–18.47</td>
<td>8.439–18.47</td>
</tr>
<tr>
<td>Zirconia abutment</td>
<td>6.06 ± 3.2</td>
<td>1.13–14.76</td>
<td>4.318–14.76</td>
</tr>
</tbody>
</table>

### Table 6: Results of Post Hoc Pairwise Comparisons with Bonferroni Correction (α = .05)

<table>
<thead>
<tr>
<th>P values</th>
<th>Titanium abutment</th>
<th>Gold-anodized titanium abutment</th>
<th>Pink-anodized titanium abutment</th>
<th>Zirconia abutment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peri-implant</td>
<td>Coronal level</td>
<td>Peri-implant</td>
<td>Coronal level</td>
</tr>
<tr>
<td></td>
<td>soft tissue level</td>
<td></td>
<td>soft tissue level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coronal level</td>
<td></td>
</tr>
<tr>
<td>Titanium abutment</td>
<td>.011</td>
<td>&gt; .999</td>
<td>&gt; .999</td>
<td>.000</td>
</tr>
<tr>
<td>Gold-anodized titanium abutment</td>
<td>.011</td>
<td>.719</td>
<td>&gt; .999</td>
<td>.018</td>
</tr>
<tr>
<td>Pink-anodized titanium abutment</td>
<td>&gt; .999</td>
<td>.027</td>
<td>&gt; .999</td>
<td>.000</td>
</tr>
<tr>
<td>Zirconia abutment</td>
<td>.000</td>
<td>.042</td>
<td>.018</td>
<td>.371</td>
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</table>

### Table 7: Correlation Coefficients Between Mean ∆E Values and Thickness of Peri- implant Soft Tissue (α = .05)

<table>
<thead>
<tr>
<th>Abutment material</th>
<th>Pearson’s correlation coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium</td>
<td>−0.544</td>
<td>.024*</td>
</tr>
<tr>
<td>Gold-anodized titanium</td>
<td>−0.393</td>
<td>.119</td>
</tr>
<tr>
<td>Pink-anodized titanium</td>
<td>−0.486</td>
<td>.048*</td>
</tr>
<tr>
<td>Zirconia</td>
<td>−0.313</td>
<td>.238</td>
</tr>
</tbody>
</table>

*Statistically significant.
with pink-anodized ones regardless of the measurement zone. Although the correlation coefficient could be considered low, the results with gold-anodized titanium were comparable to that of zirconia at the tissue level with the increase in tissue thickness. The results, however, need to be verified in a larger sample.

The favorable mechanical properties of titanium still make this abutment material the material of choice in implant dentistry. Thus, gold anodization of titanium could be advocated when titanium abutments are indicated. In a similar study, zirconia abutments also displayed significantly smaller spectrophotometric gingival color difference (ΔE) compared with titanium and gold-hued titanium abutments, respectively (3.98 ± 0.99; 7.22 ± 3.31; 5.65 ± 2.11).\(^\text{*}\)\(^{35}\) The results of the present study are twice as high as that of this study at the tissue level. This could be attributed to the fact that the zirconia abutments in this study were bonded to the titanium base, which causes some degree of shine through at the cervical region. Zirconia abutments should typically have 0.8-mm wall thickness.\(^\text{*}\)\(^{36}\) For this reason, bonding the zirconia abutment on a titanium base increases its mechanical durability. Furthermore, this design that precludes contact between the titanium implant and the zirconia abutment could avoid areas of pigmentation in the mucosa overlying the implant-abutment connection.\(^\text{*}\)\(^{16}\) The slightly higher results with the titanium abutments at the tissue level could be simply due to the thin peri-implant tissue level, which was present in the majority of the patient cohort.

The optical appearance of implant-borne reconstructions varies depending on the mucosal thickness up to 2 mm.\(^\text{*}\)\(^{37,38}\) In this study, the majority of the patients presented mean peri-implant soft tissue thickness < 2 mm with a mean of 1.46 ± 0.2 mm, and only three patients had > 2 mm tissue thickness. Yet, tissue thickness did not affect the ΔE values at the peri-implant soft tissue level for zirconia and gold-anodized titanium abutments. In fact, the biotype of the patients involved in this study could mainly be considered thin, representing more esthetically demanding situations. This indicates that both zirconia and gold-anodized titanium abutments could be suitable for anterior implant-borne single crowns as opposed to nonanodized titanium and pink-anodized ones. In a > 2-mm-thick biotype, the optical outcome at the tissue level could be similar, which needs to be verified in future studies.

Although some authors\(^\text{*}\)\(^{23,24}\) considered ΔE difference (discrepancy between two hue values) of 3 units as an indicator for visible mismatch in color, according to other studies on color stability, a color change is said to be clinically visible in any site with ΔE data that is higher than 3.7 units.\(^\text{*}\)\(^{25,26}\) According to one other study, the average casual viewer can notice the difference between two colors that are 5 to 6 ΔE apart.\(^\text{*}\)\(^{27}\) On the other hand, an educated eye could differentiate two colors that are closer to ΔE values of 3 to 4. Also, the human eye is very sensitive to changes away from achromatic tones (\(a^*\) and \(b^*\) values near 0). Thus, a difference between two “shifted” grays of ΔE with 0.5 apart could be noticed.\(^\text{*}\)\(^{27}\) Overall, ΔE = 0 to 2 is considered imperceptible, ΔE = 2 to 3 just perceptible, ΔE = 3 to 8 moderately perceptible, and ΔE > 8 markedly perceptible.\(^\text{*}\)\(^{27,28}\) Based on this information, ideally, CIELab ΔE values should have been at least lower than 3 units at peri-implant soft tissue and coronal sites so that the color difference could not be noticed by the naked eye. When this value is considered as a reference unit, in the present study, out of 20 patients, 3 of the evaluated cases showed satisfactory color matching at the peri-implant tissue level and the same 3 at the coronal level, implying that almost all abutments and implant-borne constructions were detectable to the eye. To overcome this problem, zirconia abutments were proposed to be veneered with a pink-veneering ceramic in a clinical study on 44 implant-borne all-ceramic crowns.\(^\text{*}\)\(^{39}\) However, this was not beneficial compared with native zirconia mainly due to the high translucency, which led to a decrease in brightness and eventually to a grayish discoloration of the mucosa for both screwed and cemented implant-borne crowns. Yet, in that study, implant diameter, site of the implant in the arch, including both maxilla and mandible, and the reconstructions being either screwed or cemented decreased the power of the statement made. Moreover, the type of all-ceramic material was not identified.

The measurements were made using the medium value (neutral) try-in paste to simulate a situation where a screw-retained crown was used to disclose the cement shade factor and at the same time to avoid another confounding factor. However, this could be seen as a limitation of this study for the cemented FDPs since the shade of resin cement could be chosen in a high value that could eventually mask especially the titanium abutments better than the medium value ones practiced in this study.

This study was planned to be a prospective one, and color change at both the peri-implant and coronal levels will be further evaluated. Possible color change due to aging of the ceramic, resin cement as well as the natural dentition may affect the perceptible color change over time, which will be reported in future observations.

**Conclusions**

Customized abutments made of titanium, gold-anodized titanium, pink-anodized titanium, and zirconium dioxide all demonstrated noticeable color difference.
at both the peri-implant soft tissue and coronal levels compared with the contralateral control sites for lithium disilicate single crowns. Among all abutment types, zirconia abutments showed the lowest ∆E values at both measurement zones. Soft tissue thickness did not affect the ∆E values at the peri-implant soft tissue level for zirconia and gold-anodized abutments.

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