

# Abutment Material Effect on Peri-implant Soft Tissue Color and Perceived Esthetics

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## Keywords

Peri-implant soft tissue; implant restoration; zirconia abutment; titanium abutment; implant esthetics; clinician perception; patient satisfaction.

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## Abstract

**Purpose:** The purpose of this study was to evaluate the effect of implant abutment material on peri-implant soft tissue color using intraoral spectrophotometric analysis and to compare the clinical outcomes with patient and clinician perception and satisfaction.

**Materials and Methods:** Thirty patients and four prosthodontic faculty members participated. Abutments were zirconia, gold-hued titanium, and titanium. Peri-implant mucosa color of a single anterior implant restoration was compared to the patient's control tooth. Spectrophotometric analysis using SpectroShade™ Micro data determined the color difference ( $\Delta E$ ,  $\Delta L^*$ ,  $\Delta a^*$ ,  $\Delta b^*$ ) between the midfacial peri-implant soft tissue for each abutment material and the marginal gingiva of the control tooth. Color difference values of the abutment groups were compared using ANOVA ( $\alpha = 0.05$ ). Patient and clinician satisfaction surveys were also conducted using a color-correcting light source. The results of each patient and clinician survey question were compared using chi-square analysis ( $\alpha = 0.05$ ). Pearson correlation analyses identified the relationship between the total color difference ( $\Delta E$ ) and the patient/clinician perception and satisfaction, as well as between  $\Delta E$  and tissue thickness.

**Results:** Zirconia abutments displayed significantly smaller spectrophotometric gingival color difference ( $\Delta E$ ) compared to titanium and gold-hued titanium abutments (respectively,  $3.98 \pm 0.99$ ;  $7.22 \pm 3.31$ ;  $5.65 \pm 2.11$ ;  $p < 0.05$ ). Among  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$ , only  $\Delta a^*$  (red-green spectrum) showed significant difference between groups. There was no significant correlation between measured soft tissue thickness and  $\Delta E$ , but thick gingival phenotype, determined by a probe test, demonstrated a smaller  $\Delta E$  than thin phenotype ( $4.82 \pm 1.49$ ;  $6.41 \pm 3.27$ ;  $p = 0.097$ ). There was no statistical difference in patient or clinician satisfaction among abutment materials, and no correlation between  $\Delta E$  and the patient and clinician satisfaction. Patient satisfaction was significantly higher than clinician, and patient-perceived differences were lower than clinicians' ( $p < 0.01$ ). Clinicians' satisfaction was higher for gingival (pink) esthetics than crown (white) esthetics ( $p < 0.05$ ).

**Conclusions:** Peri-implant mucosa with zirconia abutments demonstrated significantly lower mean color difference compared to titanium or gold-hued titanium abutments as measured spectrophotometrically; however, no statistical difference in patient or clinician perception/satisfaction among abutment materials was demonstrated. Patients were significantly more satisfied than clinicians.

Single-tooth implant therapy has become a widely used tooth replacement solution, and reported survival rates are consistently high.<sup>1-3</sup> The esthetic outcome regarding peri-implant soft tissues has evolved as a major focus in esthetically critical areas. The choice of different implant abutment materials may affect the color and appearance of the peri-implant soft tissue.<sup>4</sup> Several peri-implant soft tissue spectrophotometric analysis

studies using varying types of abutments (titanium, gold, or zirconia) have been completed,<sup>3,5,6</sup> but the results are conflicting. The influence of abutment material on soft tissue color was also observed by Zembic et al,<sup>5</sup> and they found no significant difference in soft tissue color change between titanium and zirconia abutments. Contrarily, Bressan et al<sup>6</sup> found that titanium abutments showed significantly greater color difference compared

**Table 1** Inclusion and exclusion criteria for patient recruitment

Inclusion criteria	Test	Dental implant patient with implant restored with a gold-hued titanium, titanium, or zirconia abutment between and including tooth #5 to #12
	Control	The same patient's adjacent or contralateral natural tooth.
Exclusion criteria	Test	Patients under age of 18, patients with acute inflammation (peri-implant mucositis) of the soft tissue around the implant, implant restorations in place less than 6 weeks.
	Control	Patients with acute inflammation of the soft tissue (gingivitis) adjacent or contralateral natural tooth, full coverage restorations on the adjacent or contralateral tooth.

to gold or zirconia abutments. Mucosa thickness and its effect on tissue discoloration has also been controversial, where one study found thickness was correlated with discoloration,<sup>7</sup> and a different study found tissue thickness did not impact the color.<sup>6</sup>

Most reports on single-tooth implant restorations have focused heavily on implant success, complications, esthetics, and to a lesser extent on patient-based outcomes,<sup>8,9</sup> but there is a need to further understand patient satisfaction with various types of implant-supported prostheses.<sup>9</sup> Available studies have not related spectrophotometrically measured gingival color to patient- or clinician-perceived esthetic acceptability. Patient-centered research regarding the contribution of gingival color perception toward achieving a predictable overall esthetic outcome is indicated.

The purpose of this retrospective clinical study was to evaluate the effect of implant abutment material on surrounding soft tissue color using intraoral spectrophotometric analysis and to compare the clinical outcomes with patient and clinician perception and satisfaction. Abutment materials included zirconia, gold-hued titanium, and titanium. The goal was to better understand patient perception and satisfaction regarding gingival esthetics and to assist clinicians in selecting implant abutment materials to optimize clinical outcomes.

## Materials and methods

The experimental design and methods described below were approved by the Institutional Review Board (IRB Protocol # 2011-1076).

### Patient recruitment

The patients for the study were identified by searching the University Prosthodontics CAD/CAM custom abutment (Atlantis; Dentsply, Waltham, MA) order list from order dates 4/15/2012 to 4/14/2013. Abutment and restoration design were confirmed through review of the electronic patient record. Patients were recruited in chronological order from the web-order log until ten patients from each abutment material (titanium, gold-hued titanium, zirconia) group were identified ( $n = 10$ ,  $N = 30$ ). Patients were contacted via phone for recall. Each patient presented with a definitive full-coverage crown cemented on a custom abutment at the time of recruitment. Inclusion and exclusion criteria for the study are shown in Table 1. Patients previously received an endosseous dental implant (Osseospeed, Astra Tech Dental Implant, Dentsply, Mölndal, Sweden) that had been placed in the maxillary anterior esthetic zone (from teeth #5 to #12). The

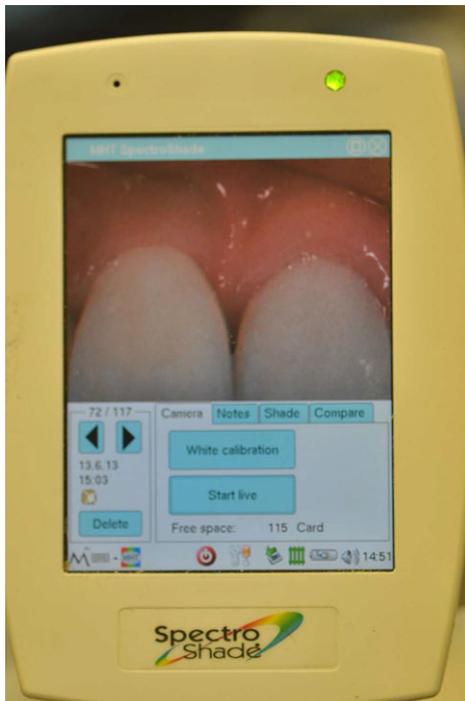
facial and interproximal margin levels of each abutment were designed at 0.5 to 1 mm subgingivally.

University faculty prosthodontists were invited to take a brief online color test voluntarily (Farnsworth Munsell 100 Hue Test; X Rite, Inc. Grand Rapids, MI. [http://www.xrite.com/custom\\_page.aspx/PageID=77&Lang=en](http://www.xrite.com/custom_page.aspx/PageID=77&Lang=en)). Four prosthodontists who demonstrated color proficiency by scoring less than 20 on the test were recruited for the study.

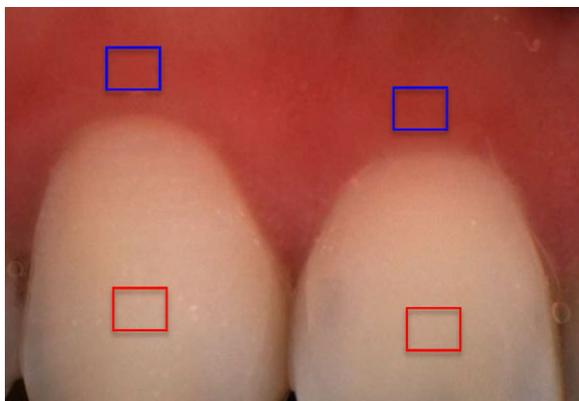
### Spectrophotometric measurements and survey

Each patient underwent spectrophotometric analysis, which consisted of color measurements of the peri-implant soft tissue (test site) and periodontal soft tissue of an adjacent or contralateral tooth (control site). Color measurements were performed with a dental intraoral spectrophotometer (Spectroshade Micro Device; Medical High Technologies, Verona, Italy, Fig 1). The instrument was calibrated prior to each data acquisition. Gingival color measurements were made of gingiva located between 1 and 4 mm apical to the free gingival margin. Measurements were also made for the crown and the control adjacent natural tooth at the middle portion of the crown or the tooth (Fig 2). The spectral data for each specimen were acquired by the captured image and transferred from the spectrophotometer to a computer for analysis. After spectrophotometric analysis, a standard dental probe was inserted in the facial gingival sulcus of a contralateral natural tooth<sup>10</sup> to predict the patient's gingival phenotype (thin or thick) as demonstrated in Figure 3.

Each participant completed a survey for perception and satisfaction of the peri-implant soft tissue color (Table 2). A handheld L.E.D. shade matching light (Rite Lite 2; AdDent Inc, Danbury, CT) was shined on the area of investigation. Patients were given a handheld mirror for visual aid while the investigator pointed to the implant and adjacent natural tooth sites. Two prosthodontists were recruited for each patient to participate in a survey of the same questionnaires as described above. Clinicians were blinded to the abutment type used for the implant restoration. To measure tissue thickness, definitive casts of the participating patients were obtained (27 out of 30 patients). All the definitive casts had poly(vinyl siloxane) soft tissue simulation around the implant analog that captured the contoured peri-implant soft tissue emergence. Midfacial mucosal thickness of the implant site was measured at the level of implant platform using a noncompressible caliper (Fig 4). Based on the



**Figure 1** An intraoral dental spectrophotometer used for the study.



**Figure 2** Demonstration of measurements taken from midfacial soft tissue of the implant site and the control site for comparison. The area of gingiva located between 1 mm and 4 mm apical to free gingival margin was selected for L\*, a\*, b\*, and ΔE measurements. The center of the crown and the adjacent natural tooth were selected as well for L\*, a\*, b\*, and ΔE measurements.

measurements, each was divided into one of the two groups (thick group: ≥ 2 mm; thin group: < 2 mm) for comparison.

**Statistical analysis**

The color difference between control and test sites (ΔE) was calculated using the formula shown in Table 3. The spectrophotometer provided a calculation of difference for each L\*, a\*, and b\* value from test and control sites. The color difference values (ΔE, ΔL\*, Δa\*, Δb\*) from each patient were summed, and means and standard deviations were calculated separately



**Figure 3** Demonstration of the probe test to determine the gingival phenotype.

**Table 2** Survey questions for patients and clinicians

<p><b>1. Are you satisfied with <u>gum color</u> above the implant crown compared to the gum color of the adjacent tooth? Please circle.</b></p>				
1	2	3	4	5
Very unsatisfied	Unsatisfied	Indifferent	Satisfied	Very satisfied
If unsatisfied, why?				
<p><b>2. Are you satisfied with <u>crown color</u> of the implant crown compared to the color of the adjacent tooth? Please circle.</b></p>				
1	2	3	4	5
Very unsatisfied	Unsatisfied	Indifferent	Satisfied	Very satisfied
If unsatisfied, why?				
<p><b>3. Do you see a difference in gum color between the implant crown and the adjacent tooth? Please circle Yes or No.</b></p>				
If yes, rank the difference on the scale of 1-5.				
1	2	3	4	5
Minimal difference				Maximal difference
If yes, does the gum color difference affect your satisfaction? Yes or No.				
<p><b>4. How important is gum color to your overall satisfaction of implant treatment?</b></p>				
1	2	3	4	5
Least important	Somewhat important	Average importance	Very important	Most important

by the abutment groups. Data were compared using one-way ANOVA (α = 0.05) to assess the difference between groups for each color parameter based on tissue thickness.

Patient and clinician survey results from each group of abutment materials were summed, and means and standard deviations were calculated among the abutment groups. Comparisons by question were made using ANOVA (α = 0.05). The results from each question of the patient and clinician survey were compared using chi-square analysis (α = 0.05). Pearson correlation analyses identified the relationship between the total



**Figure 4** Demonstration of tissue thickness measurement from soft tissue simulation on each patient's definitive cast.

**Table 3** Formula used in this study to calculate  $\Delta E$ ,  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  by comparing values from control and test group

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

$$\Delta L^* = L_{\text{control}}^* - L_{\text{test}}^*$$

$$\Delta a^* = a_{\text{control}}^* - a_{\text{test}}^*$$

$$\Delta b^* = b_{\text{control}}^* - b_{\text{test}}^*$$

color difference ( $\Delta E$ ) and the patient/clinician perception and satisfaction, as well as between  $\Delta E$  and tissue thickness.

## Results

Spectrophotometric measurements ( $\Delta E$ ,  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$ ) for peri-implant mucosa around implant crowns with titanium, gold-hued titanium, and zirconia abutments and mucosa of the respective control are shown in Table 4. All three abutments displayed the color difference ( $\Delta E$ ) compared to the respective patient control as measured spectrophotometrically (Table 5). The color change ( $\Delta E$ ) induced by zirconia and titanium abutments was significantly different. Among  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  between test and control sites, only  $\Delta a^*$  showed a significant difference between titanium and zirconia abutments (Table 5). This difference indicated a shift on the red-green color axis toward green for titanium abutments. There was no significant correlation between measured soft tissue thickness and color difference ( $\Delta E$ ); however, thick tissue phenotype, as determined by the probe test,<sup>10</sup> demonstrated a smaller mean  $\Delta E$  than thin phenotype ( $4.82 \pm 1.49$ ;  $6.41 \pm 3.27$ ;  $p = 0.097$ ). For any single patient, color perception was in agreement between the two clinicians. A positive correlation was present between the two participating clinicians for gingival color perception (Question 3; Table 2; chi-square Pearson  $\rho = 0.74$ ). Clinician-perceived differences in soft tissue color were higher than the patients ( $1.3 \pm 1.1$ ;  $0.3 \pm 0.6$ ;  $p < 0.01$ ). Clinicians' satisfaction with gingival color was also positively correlated (Question 1; Table 2; chi-square Pearson  $\rho = 0.72$ ). Satisfaction was in agreement between the two clinicians. Clinicians' satisfaction of soft tissue esthetics was lower than that of the

patients' ( $4.1 \pm 0.8$ ;  $4.7 \pm 0.5$ ;  $p < 0.01$ ). When greater gingival color discrepancy existed, clinicians had a lower gingival color satisfaction. No correlation (Pearson  $\rho = 0.10$ ) was present for the importance of gingival esthetics for overall satisfaction (Question 4; Table 2) between clinicians. A negative correlation was found between clinician satisfaction (Question 1; Table 2) with gingival color and the spectrophotometric-measured gingival color discrepancy (Question 3; Table 2; chi-square Pearson  $\rho = -0.71$ ). Patient and clinician satisfaction regarding peri-implant gingival color showed no correlation (Question 1; Table 2; chi-square Pearson  $\rho = -0.007$ ). Patient and clinician satisfaction with final crown restoration color also showed no correlation (Question 2; Table 2; Pearson  $\rho = -0.068$ ).

Patient satisfaction was significantly higher than clinician satisfaction. For clinicians, when greater gingival color difference existed, less gingival color satisfaction was noted ( $\rho = -0.81$ ). This was not the trend among patients ( $\rho = -0.277$ ). When patient and clinician satisfaction were compared, a significant difference existed for gingival color esthetics ( $\rho = -0.007$ ). Significant differences between patients and clinicians also existed for final crown restoration color ( $\rho = -0.068$ ). Importantly, there was no significant difference in patient and clinician satisfaction for any of the abutment materials ( $p > 0.1$ , ANOVA).

## Discussion

If a critical threshold of  $\Delta E = 3.7$  for intraoral color distinction by the naked eye was considered,<sup>11</sup> the spectrophotometrically measured soft tissue color with all three abutment materials indicated a visibly perceivable color difference overlying the assessed implant abutments compared to the control. Titanium abutments showed the greatest degree of soft tissue color difference ( $\Delta E$ ), which was significantly higher ( $p = 0.016$ ; Table 5) than zirconia abutments. Gold-hued titanium abutments displayed a lower mean of tissue color difference compared to regular titanium abutments, but the difference was not statistically significant. This finding is in agreement with a previous *in vivo* study that found titanium abutments were linked to significant color difference compared to gold or zirconia abutments.<sup>6</sup>

Underlying abutment material may be more important than crown material in determining soft tissue color adjacent to implant restorations. In addition to the abutment material, the crown restoration material choice may be a factor that affects marginal gingiva color. In this study, all of the titanium and gold-hued titanium abutments were restored with porcelain-fused-to-metal (PFM) crowns, and all zirconia abutments were restored with all-ceramic crowns. Although not a focus for this study, the statistical analysis of outcomes between combinations of the gold-hued titanium abutment with a PFM crown compared to a zirconia abutment with an all-ceramic crown showed no significance difference ( $p = 0.3$ ; ANOVA). The influence of abutment material on soft tissue color was also observed by Bressan *et al*,<sup>6</sup> who compared zirconia and gold abutment with the same all-ceramic crown material. They also found no significant difference in soft tissue color change between two abutment materials. If the metal ceramic crown

**Table 4** Spectrophotometric raw measurement averages and standard deviations of the peri-implant soft tissue around implant crown with titanium, gold-hued titanium, and zirconia abutment and mucosa of the control tooth (CIE-Lab parameters L, a, and b)

	L*	a*	b*
Ti (n = 10)	49.4 ± 3.4	19.4 ± 4.3	19.7 ± 13.1
Gold-hued Ti (n = 10)	49.2 ± 5.1	21.5 ± 7.6	16.3 ± 5.8
ZrO <sub>2</sub> (n = 10)	50.2 ± 4.1	23.3 ± 2.9	16.9 ± 1.8
Control for Ti (n = 10)	52.8 ± 2.7	23.8 ± 3.7	22.5 ± 11.7
Control for gold-hued Ti (n = 10)	51.0 ± 5.3	24.0 ± 6.3	18.4 ± 5.2
Control for ZrO <sub>2</sub> (n = 10)	51.4 ± 5.2	23.3 ± 2.9	18.0 ± 2.4

restoration had a significant impact on tissue color compared to the abutment material, we would have seen a statistical difference in tissue color change in this study between the gold and zirconia abutment groups. Since no statistical difference was observed between these two groups, it appears that abutments may be the critical contributor to soft tissue color change.

The current study included only cement-retained type restorations with margin levels of the abutments designed to be 0.5 to 1 mm subgingivally. Therefore, it is important to note that tissue color change in cement- or screw-retained restorations with deeper margin placements will be less likely to be affected by underlying abutment or crown margin materials.

There was no significant correlation between measured soft tissue thickness and color difference ( $\Delta E$ ). A previous *in vitro* animal study<sup>7</sup> found that soft tissue thickness and tissue discoloration of underlying materials were correlated. They found that the underlying zirconia specimen required 2 mm of tissue where the titanium specimen required 3 mm of tissue to mask the measurable color change ( $\Delta E$ ) caused by the materials; however, an *in vivo* study<sup>6</sup> found no significant difference in mucosa color between two tissue thickness groups dichotomized at measured thicknesses of 2 mm. The results from the current study are in agreement with the latter *in vivo* study.

On the other hand, a clinically determined<sup>10,12</sup> gingival phenotype may have an effect on the magnitude of measurable tissue color change. Unlike tissue thickness measurements alone, clinically determined (with probe test) tissue phenotype showed correlation with the tissue color difference ( $\Delta E$ ) ( $p = 0.097$ ). An explanation may be that, unlike popular belief,<sup>7</sup> tissue thickness may not be the only critical factor that influences the amount of gingival color change. In addition to tissue thickness, the coloration/translucency of the tissue is determined by the degree of keratinization and the distribution and number of blood vessels.<sup>13</sup> Thus, the color change of the tissue caused by underlying materials perhaps also needs to be viewed multi-dimensionally. Although historical nomenclatures such as “thick” and “thin” have been used to describe different tissue types, there is a need to understand that tissue color can be affected by multiple factors such as tissue translucency,<sup>14</sup> keratinization, and vascularity,<sup>13</sup> in addition to its thickness. This can possibly explain why the measured thickness alone did not show a significant difference, but clinically determined tissue types, which evaluated the overall perceived translucency of the underlying material (probe), showed substantial difference in tissue color change. A clinically determined tissue type takes into account all of these variables, including thickness. There-

fore, the clinically performed probe test and perceived translucency are potential predictors in determining the amount of soft tissue color change based on how these factors interact for an individual patient.

This study found that patients' color perception of tissue color was lower than the clinicians. This result is also consistent with previous reports that indicated dental care professionals, who routinely match shades for restorative treatment needs, have a higher level of sensitivity to color discrepancy.<sup>15,16</sup> Results, however, do suggest that patient color perception could also be inversely related to patient satisfaction. Discrepancy between patient and clinician satisfaction with color and esthetics is well documented. One study<sup>17</sup> has demonstrated that esthetic discrepancies existed between various dental specialties and laypeople, and that laypeople had a more forgiving assessment of what constitutes a favorable outcome in the dental setting. Another study noted that laypeople did not necessarily have similar preferences in esthetic displays among themselves, which indicated the necessity to understand patient-specific expectations.<sup>18</sup>

The visible critical color discrepancy threshold for tooth color has been determined<sup>11</sup> to be  $\Delta E = 3.7$ . When clinician's satisfaction on implant crown color was cross-tabulated using the chi-square test by two groups (group 1:  $\Delta E < 3.7$ ; group 2:  $\Delta E \geq 3.7$ ), where  $\Delta E$  indicates color discrepancy between crown and adjacent natural tooth), the result was significant ( $p = 0.08$ ). This result is, therefore, in accordance with previous findings of critical visual color threshold  $\Delta E = 3.7$  by indicating that when  $\Delta E \geq 3.7$ , color satisfaction was significantly different than  $\Delta E < 3.7$ ; however, there is no specific threshold  $\Delta E$  value reported and verified in the literature for gingival color (pink) for visibly detectable color discrepancy. Thus, chi-square correlation between gingival color satisfaction and  $\Delta E$  of the gingival color difference was conducted. It was found that gingival satisfaction was negatively correlated with  $\Delta E$  ( $\rho = -0.711$ ), which implies that when  $\Delta E$  was larger between peri-implant and control soft tissue, clinicians were less satisfied. Further studies are indicated to identify the  $\Delta E$  level necessary for the perceivable color difference so that more predictable pink esthetic results can be obtained.

Clinician satisfaction was greater for gingival (pink) esthetics than crown (white) esthetics (Question 1 and 2; Table 2;  $p < 0.05$ ; paired *t*-test). Less satisfaction was observed with crown color esthetics when a similar amount of color difference ( $\Delta E$ ) was noted with gingival color esthetics. This may be because dentists are trained to match tooth shades for restorative

**Table 5** Spectrophotometric comparative measurement differences between the peri-implant soft tissue around titanium, gold-hued titanium, and zirconia abutment and respective controls (CIE-Lab parameters L, a, b, and E)

	$\Delta L^*$	$\Delta a^*$	$\Delta b^*$	$\Delta E$
Ti	3.95 ± 2.15	4.4 ± 3.09*	3.02 ± 2.44	7.2 ± 3.3*
Gold-hued Ti	3.52 ± 2.04	2.89 ± 1.55	2.21 ± 2.21	5.7 ± 2.1
ZrO <sub>2</sub>	1.15 ± 3.23	1.85 ± 1.17*	1.95 ± 1.15	4.0 ± 1.0*
	$p > 0.05$	$p = 0.039$	$p > 0.05$	$p = 0.016$

treatment on a daily basis, and thus they may perceive the difference in tooth color more readily than the difference in gingival color. In addition, the natural gingival color varies significantly among individuals and also within the same individual, creating difficulty in matching the gingival shade when artificial pink gingiva is used. For this reason, clinicians may be more lenient with color differences of gingival color. Furthermore, not everyone has a high smile line, and gingival display varies upon speaking and smiling. Because of the varying factors in patient presentation, tissue color, and individual perceptions, clinicians may be less critical about the gingival color match.

A recent study<sup>19</sup> compared objective and subjective evaluation of peri-implant soft tissue color and found that the median color difference that corresponded to a good match was  $\Delta E = 9.74$ . This value is much higher than the thresholds for acceptability reported in the literature. This finding indicates that this value is higher than the visible critical color discrepancy threshold for tooth color,<sup>11</sup>  $\Delta E = 3.7$ . The study concluded that the human eye might be more sensitive to differences in white color (teeth) than to pink color (gingiva). This result is consistent with the current study's finding that clinician satisfaction was greater for gingival (pink) esthetics than crown (white) esthetics when a similar amount of color discrepancy existed.

The most significant finding from the current study is that there was no statistical difference in patient or clinician satisfaction among varying abutment materials ( $p > 0.1$ , ANOVA). This result may indicate that although spectrophotometric analysis yielded a significantly different color change ( $\Delta E$ ) between the titanium and zirconia abutments, the color difference may not affect the satisfaction among clinicians and patients; however, for this study the choice of abutment material was not randomized at the time of treatment. Restoring clinicians determined the abutment material based on many factors such as personal preferences and experience with different abutment materials, and patient factors including tissue type, patient expectation, age, and sex. Thus, future prospective studies using randomized selection of abutment materials will be useful in further assessment on this topic.

## Conclusions

This study related spectrophotometrically measured gingival color to patient- and clinician-perceived esthetic acceptability. The following conclusions can be drawn:

1. As measured spectrophotometrically, zirconia implant abutments demonstrated significantly lower color difference than titanium or gold-hued titanium abutments.
2. No statistical difference in patient or clinician perception/satisfaction among abutment materials was demonstrated.
3. Patients were significantly more satisfied than clinicians with gingival esthetics surrounding the implant restoration.
4. Clinicians were less satisfied with higher gingival color differences (greater  $\Delta E$ ) than patients.
5. Clinician satisfaction was higher for gingival esthetics than crown esthetics.
6. The measured thickness of the peri-implant mucosa did not influence the abutment effect on tissue color, whereas clinically determined gingival phenotype better predicted color change.

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