Optical phenomenon of peri-implant soft tissue. Part II. preferred implant neck color to improve soft tissue esthetics

Key words: dental implants, esthetics, gingival color, gingival translucency, ITI, marginal gingiva, peri-implant mucosa, soft tissues

Abstract

Objectives: The purpose of this study was to investigate an optical solution to eliminate the undesirable shine-through effect of implants on peri-implant mucosa by selecting an optimized implant neck color based on an objective and quantifiable method.

Material and methods: The optical effect of color strips on 15 peri-implant mucosal sites of 14 patients with Straumann single-tooth implant replacements in the maxillary anterior region was analyzed. The color differences between the peri-implant mucosa with insertion of each of eight different color strips (white, black, light pink, pink, light orange, orange, gold, violet) and the gingiva of an adjacent or contralateral tooth without any color strips were compared for the selection of optimal color of implant neck. Spectrophotometric color measurements were performed to compare the color difference index ($\Delta E$) and color coordinates ($D_L$, $D_A$, $D_B$ and $D_C$).

Results: The colors of the peri-implant mucosa with color strips and the gingiva of natural tooth demonstrated that the test site soft tissue with color strips of light pink, pink, light orange and orange showed a significantly smaller $\Delta E$ value ($P<0.05$). Moreover, light pink exhibited the lowest mean $\Delta E$ value of 2.6 ± 0.6, indicating a clinically indistinguishable color difference.

Conclusions: The results suggest that it is possible to improve gingival esthetics by coloring the implant neck, most effectively with light pink, to mask the impact of the underlying titanium implant. The use of implants with optimized neck colors to correct an esthetic deficiency may be a feasible approach to establish improved peri-implant soft tissue esthetics.

Predicable esthetic outcome of dental implant therapy can be achieved by a combination of correct diagnosis, treatment planning and surgical techniques. Recently, a paradigm shift has occurred in esthetic implant dentistry with a new emphasis on the soft tissue associated with the implant and its restoration. Esthetic problems arising from soft tissue-related deficiencies are observed with renewed interest in maxillary anterior single-tooth implant-supported restorations. Studies indicated that a stable vertical and horizontal dimension of healthy periodontal soft tissue, the biological width, is an important factor in the consideration of soft tissue esthetic result (Abramsson et al. 1996; Berglundh & Lindhe 1996; Cochran et al. 1997; Hermann et al. 2000, 2001).

In conjunction with the optimal biological width establishment, the potential for soft tissue recession around individual implants must be considered for final esthetics. Gingival recession at the facial aspect of the dental implant can cause unacceptable soft tissue esthetics and jec-
reduce the implant-related optical problem of peri-implant tissue.

The purpose of this study was to investigate the optical effects of eight different implant neck colors transmitted through the peri-implant marginal mucosa, and to provide an optical solution for eliminating the undesirable shine-through effect by selecting an optimized implant neck color based on an objective and quantifiable method.

Material and methods

The color differences between the peri-implant mucosa with the insertion of each of eight different color strips and the gingiva of adjacent or contralateral tooth without color strips were compared. The optical effects of color strips were examined by comparing the colors of the gingiva of adjacent or contralateral natural tooth (control site) and the peri-implant mucosa (test site). The most effective color strip that provided an indistinguishable difference in color for the peri-implant mucosa compared with the control site was identified.

Human subjects and implants

Subjects who had already received Straumann® implants (Institut Straumann AG, Waldenburg/BL, Switzerland) during the past 5 years for single-tooth implant replacements in the maxillary anterior region were recruited from the patient pool at the Harvard School of Dental Medicine. During the first visit, an initial examination including the location of the soft tissue margin, plaque index, bleeding on probing, probing depth and implant mobility was performed. Subjects with periodontal and peri-implant health that was within the normal limit were included in the study. The patients who met the study eligibility criteria were invited to a second visit for color measurement and gingival thickness. Fifteen sites from 14 patients were included in this study. This study was approved by the Institutional Review Board (IRB) at Harvard Medical School.

Color strips

Eight color strips (white, black, light pink, pink, light orange, orange, gold, violet) were considered for the selection of optimal color of implant neck [Table 1]. The color strips were made of high-quality, high-gloss paper (Koseki Co., Iwate, Japan) in a rectangular shape of 2 mm width and 4 mm length with a thickness of 30 μm. Each strip was for single use and was sterilized by an alcohol solution (75% ethanol) insertion.

Color measuring instrument

Spectrophotometric measurements were made using a multi-spectral camera system (Handy-MSC, Olympus Co., Tokyo, Japan) as shown in Fig. 1. This spectrophotometer (Handy-MSC) uses a new technique of multi-band image acquisition with a built-in LED lamp in the measuring head as a light source. Eight LED lamps (Olympus Co.) were used as a source of illumination. The area of illumination was 20 mm in diameter with a central area of 15 mm in diameter for measurement. Spectra data acquisition required about 0.2 seconds. The spectrophot-

Table 1. Optical data for color strips used in this study: L* (lightness), a* (redness) and b* (yellowness)

<table>
<thead>
<tr>
<th>Color of strip</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>79.6</td>
<td>1.788</td>
<td>3.68</td>
</tr>
<tr>
<td>Light pink</td>
<td>5.16</td>
<td>33.912</td>
<td>-5.044</td>
</tr>
<tr>
<td>Pink</td>
<td>61.143</td>
<td>31.539</td>
<td>5.953</td>
</tr>
<tr>
<td>Light orange</td>
<td>64.771</td>
<td>20.966</td>
<td>22.207</td>
</tr>
<tr>
<td>Orange</td>
<td>55.925</td>
<td>28.076</td>
<td>5.328</td>
</tr>
<tr>
<td>Violet</td>
<td>38.729</td>
<td>14.545</td>
<td>2.299</td>
</tr>
<tr>
<td>Gold</td>
<td>47.144</td>
<td>0.912</td>
<td>27.711</td>
</tr>
</tbody>
</table>

(Mean ± standard deviation, n = 15.)
Color measurements

The spectrophotometric color measurement was performed using the following procedures.

1. The color of the soft tissue of the test site was measured before insertion of the strips. Each of eight strips was inserted into the peri-implant mucosal sulcus of the test site. Strips were slightly bent according to the curve of implant neck to avoid any pressure to the soft tissue. After 5 min, to allow the soft tissue to settle, the color of the pre-implant mucosa (test site) with each of eight color strips was measured in three incremental areas [Fig. 1].

2. The color of the gingiva of adjacent or contralateral tooth of the test site was measured as a control [Fig. 2].

Data analysis

The color of test site with and without color strips was compared for color difference index ($\Delta E$) and color coordinates ($\Delta L^*$, $\Delta a^*$, $\Delta b^*$ and $\Delta C^*$), and the optical effect of color strips on peri-implant mucosa was analyzed. Furthermore, the color of the test site with each of eight color strips was compared with the color of the control site, and the most effective color strip indicating the smallest $\Delta E$ was determined. According to the CIELAB units, close color mismatch was in the range of two to four $\Delta E$ units. A $\Delta E$ of $<1$ was considered to be excellent and that of over 3.6 was considered to be a clinically distinguishable color difference [Ruyter et al. 1987; Johnston & Kao 1989; Ishikawa-Nagai et al. 2005].

Statistical analysis

Statistical analyses were performed using Statcel computer software (OMS, Ltd., Saitama, Japan) and data were expressed as the mean $\pm$ standard deviation. Outcome values ($\Delta E$, $\Delta L^*$, $\Delta a^*$, $\Delta b^*$) were plotted and skewness and kurtosis values were computed to evaluate the normality of the distributions. Those distributions with confirmed normality were analyzed using parametric methods (one-way ANOVA), and Fisher’s PLSD was chosen for multiple comparisons.

Results

Optical data for color strips used in the study are described in Table 1. Color differences in the peri-implant mucosa with and without the color strips revealed that all color strips except for gold resulted in clinically distinguishable color changes ($\Delta E \geq 3.6$) compared with the peri-implant mucosa without any color strip [Fig. 3]. The gold color strip had less apparent effect on the peri-implant mucosa with a mean $\Delta E$ value of 3.39. Upon further analysis, light pink, pink, light orange and orange color strips showed an increase in both $L^*$ and $a^*$ values, indicating a positive effect against the underlying titanium implant color [Fig. 4]. Colors violet and gold showed a negative change in $L^*$ and $a^*$, contributing to a darkening effect of the peri-implant tissue.

A comparison of colors of the peri-implant mucosa (test site) with color strips and the gingiva of natural tooth (control site) demonstrated that the test site soft tissue with strips of light pink, pink, light orange and orange showed a significantly smaller $\Delta E$ value ($P<0.01$) compared with other color strips. Moreover, light pink exhibited the lowest mean $\Delta E$ value of $2.12 \pm 0.6$. The mean $\Delta E$ value for color pink was $3.3 \pm 0.7$ compared for light pink and gold caused a dramatic decrease in $L^*$ while light pink caused a strong increase in $L^*$ compared with the gingiva of the natural tooth as a control site [Fig. 5]. In terms of color coordinates, a white strip resulted in a small $\Delta E$ while violet and gold caused a decrease in $L^*$ compared with the gingiva of the natural tooth as a control site [Table 2]. Light pink, pink, light orange and orange strips produced colors of peri-implant mucosa with chromaticity and lightness similar to the control site [Fig. 6].

Discussion

The results of the present study demonstrated that the color of peri-implant tissue...
can be altered through the insertion of colored strips. Color differences of per-implant tissue with and without color strips revealed similar values of color difference ($D_E$) among the colors white, light pink and violet (Fig. 3), however; white and violet color strips had an overall negative effect on the per-implant tissue. This can be explained by the analysis that white had a significantly large $D_L$ value with very low $D_a$ indicating increased lightness but reduced redness. On the other hand, color violet had low $D_L$, $D_a$ and $D_b$ values, signifying darkness, less redness and less yellowness, respectively. The $D_L$ (lightness or value) is the most significant parameter because the human eye can detect changes in value more readily than it can perceive changes in hue. A $D_L$ value of $< 2$ and a total $D_E$ of $< 4$ have been shown to represent clinically acceptable color matching [Ruyter et al. 1987; Johnston & Kao 1989; Paul et al. 2002; Ishikawa-Nagai et al. 2005].

The goal of evaluating the color difference is to achieve the smallest $D_E$ value possible, indicating the most accurate shade match. Following insertion of light pink, pink, light orange and orange color strips, a less color difference in peri-implant tissue was measured compared with the corresponding adjacent or contralateral natural gingiva. When a color strip was darker than the target color of the adjacent or contralateral control sites as was the case with colors violet and gold, the color difference was greater. Dark color strips negatively affected the peri-implant tissue esthetics in terms of color as soft tissue is partially translucent. When colors similar to that of natural gingival tissue was used for the implant neck, the test site was able to reproduce the target color more satisfactorily.

Concepts of implant placement and restoration have been developed and described in the literature. However, most published studies do not include well-defined esthetic parameters [California Dental Association 1977; Chang et al. 1999; Touati et al. 1999]. The crown margin in areas of thin gingiva is usually supragingival, resulting in a poor esthetic appearance. Oates et al. [2002] suggested that on the facial aspect of 61% of the 106 implants, there was 1 mm or more of soft tissue recession, whereas 19% of the implants showed 1 mm or more of gain in soft tissue height over a 2-year period. A study by Chang et al. [1999] indicated that the gingival margin on the facial aspect of the implants was located more at the apical than the gingival margin level on the adjacent teeth, suggesting soft tissue recession. In addition, subsequent recession of the soft tissue margin following crown placement has been reported [Adell et al. 1990; Apse et al. 1991; Jemt et al. 1994; Bengazi et al. 1996].

It is also necessary to minimize the gray color associated with the metal component showing through the peri-implant tissue. One approach focuses on the implant components such as ceramic abutments [Andersson et al. 2001; Brodbeck 2003].
Zirconium oxide and aluminum oxide ceramic abutments offer esthetic results because of their ability to allow transmission of light. Zirconia abutments have shown survival rates and fracture strengths similar to metal abutments and offered sufficient stability to support implant-supported restorations (Glauser et al. 2004; Butz et al. 2005). At the same time, the ability to fabricate ceramic abutments to the same precision as metal abutments has been questioned. A resultant imprecise fit between the abutment and implant can lead to screw loosening and wear at the ceramo-metal interface in two-piece implants. Furthermore, bone loss due to infiltration of microorganisms through the microgap could lead to an array of problems (Binon 2000).

Although a ceramic abutment can help avoid the dark color appearance at the gingival margin, the opaque white color inherent in the ceramic material poses a disadvantageous effect in patients with parts of the abutment that are not covered by the gingiva or show through the thin gingival tissue. Color matching of the abutment was recommended under all-ceramic crowns in cases of inadequate thickness of the ceramic. Ceramic thickness of $\leq 1.5$ mm has been shown to influence the final shade from the color of abutment underneath the crown (Vichi et al. 2000; Nakamura et al. 2002). Thus, there is substantial merit in studying implants with specific neck colors to improve soft tissue appearance.

The ultimate success of implant esthetic is attributed to establishment of peri-implant soft tissue esthetics. No current methods available in implant dentistry offer solutions to eliminate the fundamental problem arising from positioning of the implant in relation to the gingival margin. However, through promising results from the present study, the authors would like to suggest that it is possible to improve gingival esthetics by coloring the implant neck to mask the underlying titanium implants. The use of preferred neck color implant to correct an esthetic deficiency may be a feasible approach to establish optimal peri-implant soft tissue esthetics.

**Acknowledgement:** This research was supported by the ITI Foundation research grant, Project #298/2003.

### Table 2. Optical differences ($\Delta E$, $\Delta L^*$, $\Delta a^*$ and $\Delta b^*$) between the gingiva of natural tooth (control site) and the peri-implant mucosa (test site) with/without color strips

<table>
<thead>
<tr>
<th></th>
<th>$\Delta E$</th>
<th>$\Delta L^*$</th>
<th>$\Delta a^*$</th>
<th>$\Delta b^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No strip</td>
<td>7.65 ± 4.21</td>
<td>-4.67 ± 4.04</td>
<td>-3.41 ± 1.77</td>
<td>-3.72 ± 3.69</td>
</tr>
<tr>
<td>White</td>
<td>7.99 ± 1.49</td>
<td>6.57 ± 1.64</td>
<td>-0.87 ± 3.00</td>
<td>0.96 ± 3.29</td>
</tr>
<tr>
<td>Light pink</td>
<td>2.13 ± 0.64</td>
<td>-0.54 ± 0.7</td>
<td>0.95 ± 0.96</td>
<td>-1.15 ± 1.08</td>
</tr>
<tr>
<td>Pink</td>
<td>3.33 ± 0.76</td>
<td>-1.95 ± 0.69</td>
<td>1.16 ± 1.38</td>
<td>-1.61 ± 1.34</td>
</tr>
<tr>
<td>Light orange</td>
<td>3.39 ± 1.02</td>
<td>-1.29 ± 1.24</td>
<td>0.84 ± 1.76</td>
<td>-2.10 ± 1.21</td>
</tr>
<tr>
<td>Orange</td>
<td>4.64 ± 2.18</td>
<td>-1.59 ± 2.71</td>
<td>1.08 ± 1.91</td>
<td>-2.86 ± 2.03</td>
</tr>
<tr>
<td>Violet</td>
<td>14.13 ± 3.49</td>
<td>-8.05 ± 2.27</td>
<td>-4.10 ± 8.37</td>
<td>-3.18 ± 7.25</td>
</tr>
<tr>
<td>Gold</td>
<td>9.39 ± 4.00</td>
<td>-4.36 ± 6.2</td>
<td>-4.22 ± 2.03</td>
<td>-4.68 ± 2.24</td>
</tr>
</tbody>
</table>

(Mean ± standard deviation, $n=15$).

**Fig. 6.** A $L^*$ and $a^*-b^*$ map of the test site with color strips and the control site.
References


Ishikawa-Nagai et al. Optical phenomenon of peri-implant soft tissue.