Assessment of Peri-implant Soft Tissue Adaptive Pressure and Time After Provisional Restorations

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Using interim restorations to remodel the peri-implant gingiva contour has been a common procedure in esthetic implant treatment. During the interim restoration delivery, the pressure between the restoration and gingiva typically causes ischemia. Adequate restoration should allow the tissue to recover from ischemia over a certain time. To assess the time needed for peri-implant soft tissue recovery, interim restorations were delivered on 25 single implant sites 2 weeks after stage-two surgery, and the gingiva appearance changes after delivery were recorded for 15 minutes using a video camera. Gingiva color changes along the time were measured and analyzed. The color differences between peri-implant mucosa at 10 min and 0 min, as well as between adjacent tooth gingiva, were all within a clinically acceptable range of color difference. The adaptive pressure technique by two-stage contouring exhibited an optimal peri-implant soft tissue profile within 10 minutes of the adaptive time. Int J Periodontics Restorative Dent 2019;39:809–815. doi: 10.11607/prd.4063

Due to a significant amount of soft and hard tissue resorption after tooth extraction, it remains challenging to achieve pleasant anterior implant esthetics that fulfill a patient’s esthetic expectations. Furthermore, the literature shows that there are different anatomical structures between implants and natural teeth, so achieving an esthetically pleasing implant restoration requires greater clinical and technical understanding. For example, in an ideal esthetic implant restoration case, the surrounding implant mucosal margin, color, texture, and contour of the peri-implant soft tissue should be harmonious with the adjacent and contralateral teeth and/or implants. To fulfill the goal of achieving a pleasing esthetic anterior implant restoration, factors such as buccal bone thickness, mucosa thickness, implant position, and the contour of the abutment and prosthesis should be properly controlled since they are known to influence the level of the peri-implant mucosal margin and soft tissue. Despite efforts to develop an ideal profile by subtracting or adding restorative materials for provisional restoration, there is no information currently available on how much pressure and how much time is required to obtain the ideal peri-implant soft tissue profile. The aim of this study was to develop and validate the adaptive pressure for...
Modification of the provisional crown contour in peri-implant mucosa and to determine the adaptive time by means of measuring color changes between the peri-implant mucosa and gingiva of an adjacent tooth.

Materials and Methods

The experiment was carried out in Xiamen Stomatological Hospital and was approved by the Institutional Review Boards of the Xiamen Medical College. Subjects with a single maxillary anterior-zone (canine to canine) implant in need of secondary implant surgery and restorations were included. Patients with thin pheno-biotype, determined by use of a probe inserted in the buccal sulcus of adjacent teeth, were excluded. A total of 25 patients (aged from 23 to 38 years) were ultimately enrolled. The keratinized mucosa thickness around an implant site was greater than 2 mm in all patients. Informed consent forms were obtained from all subjects.

An Er:YAG laser with a 2,940-nm wavelength (LiteTouch, Syneron) was used in the second phase of implant surgery. The treatment was performed using the angled handpiece with a 1.3 × 19-mm tip in contact mode. A previously made surgical template was used as a guide to locate the healing cap. A laser with a frequency of 10 Hz and a pulse power rating of 150 mJ was used to uncover all implants. No anesthesia was applied because the laser-performed second-stage surgery showed little bleeding and minimal pain or discomfort.

After the tissue covering the implant was removed, the healing cap was replaced with a standard-sized healing abutment (4.0 × 4.0 mm, Zimmer Biomet), allowing healing by secondary intention. Two weeks later, a digital impression was made using CEREC Omnicam scanner (Dentsply Sirona) to obtain a digital model. During the appointment for the digital scan, the implant site’s soft tissue thickness was measured 2 mm below the facial gingiva margin using a caliper. Tissue thickness > 2 mm was still present in all subjects.

A screw-retained implant-supported interim restoration with gold-hued titanium abutment was fabricated. Resin (Filtek Supreme, 3M) was used to shape the transmucosal part of the restoration. In the first tissue modeling stage, the convexity of the interproximal contour was increased to squeeze the interdental papillae while the facial region was kept in a concave form. This allows the buccal soft tissue to easily fill the concave space and the height of papillae to be increased.

The second tissue modeling stage began 2 weeks later (Fig 1). Patients were recalled and the restorations were retrieved. The convexity of the buccal transmucosal restoration was increased to push the gingival margin apically to the level of its contralateral tooth (Fig 2). Once the restoration was delivered, a video of the implant site was recorded for 15 minutes using a digital video camera (FDR-AX100, Sony). Frames were extracted from the 4K video at 1-minute intervals between 0 and 10 minutes and at 15 minutes (Fig 3). The color...
parameters (lightness \([L^*_x]\), green-red \([a^*_x]\) and blue-yellow \([b^*_x]\)) at the mesial, midfacial, and distal aspects of peri-implant mucosa were measured by a software program (Adobe Photoshop 7.0).\textsuperscript{12} The same measurements were assessed around the natural tooth contralateral to the implant site. Each test point was 2 mm from the gingival margin. The \(L^*_x a^*_x b^*_x\) value at the same site was assessed three times, and the mean values were calculated for future statistical analysis. The color differences (\(\Delta E^*_x\)) between the peri-implant mucosa and the natural tooth were calculated according to the Commission Internationale de l’Eclairage standard, as follows\textsuperscript{13}:

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

Where \(L^*_x\) is lightness, \(a^*_x\) is green-red (\(-a^*_x = \text{green}; +a^*_x = \text{red}\)), and \(b^*_x\) is blue-yellow (\(-b^*_x = \text{blue}; +b^*_x = \text{yellow}\)).

An \(\Delta E^*_x \leq 3.7\) is interpreted as a clinically acceptable level of no color difference.\textsuperscript{14} The subscript in \(\Delta E^*_x\) represents interval time; for example, \(\Delta E^*_{0-15}\) is the color difference obtained between 0 and 15 minutes after trying in the provisional crown.

Fig 3  Images from the 4K video, extracted at 1-minute intervals from 1 to 10 minutes and at 15 minutes, show gingival color change of the peri-implant mucosa and neighboring tooth.
The correlation between $\Delta E^*_{x}$ in 0 to 10 minutes and time was analyzed using linear regression. The color changes among 0, 10, and 15 minutes in peri-implant soft tissues and between 9, 10, and 15 minutes in peri-implant soft tissue and gingiva of the adjacent tooth (AT) were analyzed using one-way analysis of variance (ANOVA) and SNK-q (Student-Newman-Keuls) test. The level of significance was set at $\alpha = .05$.

Results

$\Delta E^{*}_{9-AT}$ was significantly different from $\Delta E^{*}_{10-AT}$ and $\Delta E^{*}_{15-AT}$ ($P < .05$) and was greater than the clinically acceptable level of 3.7 (Table 1). Among $\Delta L^*_x$, $\Delta a^*_x$, and $\Delta b^*_x$ between control and test sites, only $\Delta a^*_x$ showed a significant difference between the AT gingiva and peri-implant mucosa. There was no obvious discrepancy found between $\Delta E^{*}_{10-AT}$ and $\Delta E^{*}_{15-AT}$ ($P > .05$). The results imply that peri-implant mucosa color 10 minutes after contouring under adaptive pressure presents similar color appearance to the AT gingival color. No significant difference was present between $\Delta E^{*}_{0-10}$ and $\Delta E^{*}_{0-15}$ ($P > .05$), but both were lower than the clinically acceptable color difference (Table 2). Among $\Delta L^*_x$, $\Delta a^*_x$, and $\Delta b^*_x$, all color parameters showed significant differences in the peri-implant mucosa between 0 and 10 minutes and between 0 and 15 minutes. Therefore, the correlation between $\Delta E^{*}_{0-10}$ and adaptive time was determined, as shown in Fig 4. The ANOVA results show a correlation $R^2 = 0.8612$, which means there was high correlation between color difference and adaptive time. The slope in regression equation presented a negative correlation. Under adaptive pressure to peri-implant soft tissue, crown length at 0 and 10 minutes revealed

### Table 1 Comparative Measurement Color Changes (Mean ± SD) Between Gingiva of the Adjacent Tooth and the Peri-implant Soft Tissue at 9, 10, and 15 Minutes

<table>
<thead>
<tr>
<th>Groups</th>
<th>$\Delta L_x$</th>
<th>$\Delta a_x$</th>
<th>$\Delta b_x$</th>
<th>$\Delta E^{*}_{x}$</th>
<th>$\Delta E^{*}_{10-AT}$</th>
<th>$\Delta E^{*}_{15-AT}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>67.0 ± 1.0a</td>
<td>24.0 ± 1.0a</td>
<td>11.3 ± 0.5ab</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>9 min</td>
<td>64.3 ± 1.1a</td>
<td>20.6 ± 1.1b</td>
<td>10.1 ± 0.5a</td>
<td>4.5 ± 0.8a</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>10 min</td>
<td>65.7 ± 0.7a</td>
<td>20.6 ± 1.0b</td>
<td>12.1 ± 1.0b</td>
<td>3.7 ± 0.9b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>15 min</td>
<td>65.3 ± 0.7a</td>
<td>20.8 ± 0.6b</td>
<td>12.4 ± 0.5b</td>
<td>3.7 ± 0.9b</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

AT = adjacent tooth; SD = standard deviation. Within the same column, values with different superscript letters are statistically significantly different ($P < .05$).

### Table 2 Comparative Measurement Color Changes (Mean ± SD) Between the Peri-implant Soft Tissues at 0, 10, and 15 Minutes

<table>
<thead>
<tr>
<th>Groups</th>
<th>$\Delta L_x$</th>
<th>$\Delta a_x$</th>
<th>$\Delta b_x$</th>
<th>$\Delta E^{*}_{x}$</th>
<th>$\Delta E^{*}_{10-AT}$</th>
<th>$\Delta E^{*}_{15-AT}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>69.3 ± 1.9a</td>
<td>9.4 ± 2.3a</td>
<td>6.0 ± 1.2a</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>10 min</td>
<td>65.7 ± 0.7b</td>
<td>20.6 ± 1.0b</td>
<td>12.1 ± 1.0b</td>
<td>3.6 ± 0.9a</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>15 min</td>
<td>65.3 ± 0.7b</td>
<td>20.8 ± 0.6b</td>
<td>12.4 ± 0.5b</td>
<td>3.5 ± 0.6a</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

SD = standard deviation. Within the same column, values with different superscript letters are statistically significantly different ($P < .05$).

The correlation between $\Delta E^{*}_{x}$ in 0 to 10 minutes and time was analyzed using linear regression. The color changes among 0, 10, and 15 minutes in peri-implant soft tissues and between 9, 10, and 15 minutes in peri-implant soft tissue and gingiva of the adjacent tooth
no significant difference, with the values of 8.9 ± 0.3 mm and 9.0 ± 0.3 mm, respectively.

Discussion

Adaptive Pressure Technique

Three methods have been used to obtain the proper crown profile and contour in provisional restorations. The selective pressure method applied higher pressure in the interproximal area to support the papillae, while lower pressure was used in the undercontoured buccal gingival area to prevent recession. The dynamic compression technique involves over-contouring first, then subtracting volume in interproximal and cervical areas to create space for peri-implant soft tissue. The critical and subcritical contour technique was applied by manipulating contours in the critical (1 mm below the gingival margin) and subcritical (emergence profile apical to the critical zone) zones. All described techniques lack quantitative determinants of the location for contour modifications and timing.

The adaptive pressure technique adopted in this study was used to over-contour the mesial and distal regions to mold interproximal papilla. This is because applying pressure on the interdental tissue resulted in narrowing the embrasure space, leading to increased papilla height. It has been reported that terminal branches of larger vessels in the bone periosteum at the implant site provide blood supply for the peri-implant soft tissue, though limited blood vessels were noted in peri-implant soft tissues lateral to the implant areas. Therefore, the adaptive pressure technique controls soft tissue contouring within a physiologic tolerance. Alteration of the contour does not alter the gingival margin level significantly because the ischemic reaction fades away within 10 minutes. When the tissue-modeling stage is complete, the final restoration can be fabricated based on good pink esthetics (Fig 5).

Adaptive Time of Ischemic Reaction

The adaptive procedure of the ischemic reaction during the facial soft tissue contouring adjustment was shown in 12 frames, extracted at 1-minute intervals from 0 to 10 minutes of the video and at 15 minutes (Fig 3). The regression equation between $\Delta E_x^*$ and adaptive time presented a negative correlation and no significant difference was noted between $\Delta E_{0-10}^*$ and $\Delta E_{0-15}^*$, which meant the color in the peri-implant soft tissue gradually recovered from white to pink within 10 minutes. This implies that the shortest time for blanching disappearance was 10 minutes, indicating the time needed for the peri-implant soft tissue to bear pressure from a placed restoration. This is consistent with several studies that recommended either 10, 15, or 20 minutes of contouring time. The ischemic reaction caused by exaggerated convex contouring over a longer period of time might result in gingival edema, inflammation, and recession, and even avascular necrosis. Figure 4 clearly shows that there are two stages in the adaptive procedure of ischemic reaction: the fast stage, in which blood quickly fills in the peri-implant soft tissue during the first 4 minutes, and the slow stage, in which the gingival tension gradually
returns to normal over the following 6 minutes. This information provides details regarding the time needed for peri-implant soft tissue molding.

**Color Change in Peri-implant Mucosa and the Tooth Gingiva**

An ideal peri-implant mucosal color must match that of the adjacent teeth, provided they have the same tension. The mucosal color at 9 minutes in peri-implant showed more yellow than that at 10 and 15 minutes. Both values of \( \Delta E_{10-AT} \) and \( \Delta E_{5-AT} \) were 3.7 ± 0.9, which is equal to the clinically acceptable value for color difference (3.7).

The mucosal color in peri-implant soft tissue at 9, 10, and 15 minutes showed more red color than that of the AT gingiva. Although Paniz et al\(^2\) reported color differences between peri-implant soft tissue and gingiva of natural teeth based on spectrophotometer assessment, this difference was not observed in a subjective evaluation completed by five dental professionals (prosthodontist, periodontist, general dentist, dental hygienist, and dental assistant). Results from the present software program assessment confirmed the spectrophotometric evaluation performed by Paniz et al. There are many factors influencing the peri-implant soft tissue color, such as the thickness of the facial gingiva, abutment material, and peri-implant soft tissue architecture.\(^{25}\) To control these confounding factors in the present study and ensure consistent color measurements, a gold-hue abutment was selected and it was required that all subjects have a soft tissue thickness > 2 mm at the implant site. According to a study by Sala et al, when the gingival thickness is larger than 2 mm, a gold-hue abutment has no impact on gingival color.\(^{26}\)

**Conclusions**

This study shows that using an immediate restoration to mold soft tissue, both in the interproximal papillae and midfacial mucosa, is a feasible technique to achieve the needed aesthetic outcome. The present data also indicate that, in peri-implant soft tissue molding, 10 minutes of adaptive time is adequate for soft tissue recontouring without changing the color appearance or soft tissue margin level. Future studies in this field are needed to further confirm the validity of this novel approach.

**Acknowledgments**

The authors declare no conflicts of interest.

**References**