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BÜCHI, Dominik, et al.

Abstract
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Reference

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All-Ceramic Single-Tooth Implant Reconstructions Using Modified Zirconia Abutments: A Prospective Randomized Controlled Clinical Trial of the Effect of Pink Veneering Ceramic on the Esthetic Outcomes

Dominik L.E. Büchi, Dr Med Dent¹
Irena Sailer, Prof Dr Med Dent²
Vincent Fehmer, MDT¹
Christoph H.F. Hämmerle, Prof Dr Med Dent³
Daniel S. Thoma, PD Dr Med Dent⁴

The aim of this study was to test whether veneering of the submucosal part of zirconia abutments using pink veneering ceramic positively influences the color of the peri-implant mucosa. Single-tooth implants were restored with either white zirconia abutments (control group) or pink-veneered zirconia abutments and all-ceramic crowns. Esthetic outcome measurements included a spectrophotometric evaluation of the peri-implant mucosal color. Test and control groups induced a visible discoloration of the peri-implant mucosa after the insertion of the abutments and following cementation of the crowns compared to natural teeth. The calculated color differences were above the clinically visible threshold value and were more favorable for the control group, although not statistically significant. It is concluded that veneering of zirconia abutments with pink veneering ceramic failed to positively influence the aesthetic outcome, mostly due to a decrease of the brightness compared with the control group. (Int J Periodontics Restorative Dent 2014;34:29–37. doi: 10.11607/prd.1870)

¹Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zurich, Zürich, Switzerland.
²Chairwoman, Division of Fixed Prosthodontics and Occlusion, University of Geneva; Formerly Associate Professor, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zürich, Zürich, Switzerland.
³Professor and Chair, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zürich, Zürich, Switzerland.
⁴Associate Professor, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zürich, Zürich, Switzerland.

Correspondence to: PD Dr Daniel S. Thoma, Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, Flattenstrasse 11, 8032 Zürich, Switzerland; fax: +41 44 634 42 56; email: daniel.thoma@zzm.uzh.ch.

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Implant-supported single crowns have become a valid alternative to conventional fixed dental prostheses due to their excellent clinical long-term results.¹–³ The materials of choice for implant-borne reconstructions are metal abutments and cemented porcelain-fused-to-metal crowns.⁴ Clinical studies demonstrated excellent survival rates of metal abutments in all regions of the arches.⁵–⁷ However, the use of metal abutments is associated with some limitations and disadvantages, mainly with respect to the esthetic outcome. It is documented in clinical studies that metal abutments can cause a gray shadow and a dark discoloration in patients with thin peri-implant mucosa.⁸–¹¹ To overcome these esthetic issues associated with metal abutments, zirconia abutments were introduced in implant dentistry. Zirconia abutments offer a variety of biologic advantages, including lower bacterial adhesion,¹² more favorable biocompatibility compared with titanium,⁸,¹³,¹⁴–¹⁷ and superior biologic behavior compared to metals since ceramic does not suffer from corrosion and/or galvanic coupling.¹⁸,¹⁹ The use of zirconia
and titanium implant abutments resulted in similar clinical outcomes in a randomized controlled clinical study. No differences were found with respect to biologic and technical outcomes. It has also been demonstrated that the mechanical strength of zirconia abutments is adequate for clinical use; thus, zirconia abutments may serve as an alternative to metal abutments. Still, there is only limited scientific data for prospective controlled randomized long-term studies evaluating the clinical performance of ceramic abutments. In addition, the influence of potential disadvantages such as susceptibility to hydrolytic degradation and reduced fracture strength compared with metal abutments on the clinical long-term outcomes is unknown. In addition to these favorable biologic properties and the reported clinical outcomes, the white color of a zirconia abutment can avoid discoloration of the peri-implant mucosa and offer an esthetic benefit compared to metal abutments. However, even with white zirconia abutments, a slight discoloration of the peri-implant tissue was observed, predominantly in patients with a thin mucosa. It is speculated that further optimizations of the submucosal color of an abutment could potentially improve the esthetic outcome. The esthetic outcome of veneering the submucosal part of zirconia abutments using pink ceramics has not yet been evaluated by a randomized controlled clinical study. The aim of the present study was to test whether the color of the submucosal part of zirconia abutments can positively influence the color of the peri-implant mucosa and, thus, the esthetic outcome.

Method and materials

Study design and subjects

This study was designed as a randomized controlled clinical trial. Upon approval by the local ethics committee (KEK-ZH no. 2010-0041/5), 20 patients were recruited who had received 20 dental implants (AstraTech) in the maxilla or mandible replacing incisors, canines, or premolars. The inclusion criteria were successfully osseointegrated implants, no systemic disease, good oral hygiene, smokers and nonsmokers, and no signs of bruxism. All implants were planned to be restored with implant-borne single-tooth reconstructions using customized zirconia abutments (Atlantis shade 00, AstraTech) and all-ceramic crowns. At the time of the final impression, patients were randomly allocated to either the test (white zirconia abutment with a pink-shaded submucosal part) or control group (white zirconia abutment). A clinical case is shown in Fig 1.

Prosthetic protocol and treatment modalities

All customized zirconia abutments were fabricated by means of a computer-aided design/computer-assisted manufacturing (CAD/CAM) technique (Atlantis, AstraTech). In the test group, the submucosal part of the zirconia abutments was veneered with pink-shaded ceramic using a glass-ceramic (Creation ZI, Klema) according to the manufacturer's guidelines (Fig 1b). The optimal shade that best matched the mean color of the natural gingiva of the neighboring teeth was chosen based on the outcomes of a yet unpublished study. The thickness of the ceramic layer was standardized to 0.5 mm at the level of the abutment-crown marginal shoulder and decreased continuously toward the implant shoulder. In the control group, no modifications were applied to the white zirconia abutments (Atlantis shade 00) (Fig 1c). The dimension of the abutment and the horizontal and vertical position of the abutment shoulder were checked in a clinical try-in session. If necessary, the abutment shoulder height was modified, positioning it circumferentially 1 mm below the mucosal margin. Subsequently, all-ceramic crowns (Emax, Ivoclar Vivadent) were manufactured. The abutments were fixed with a torque of 20 Ncm onto the implants. A retraction cord (Ultrapak, Ultradent) was then placed around the abutments, and the crowns were cemented using a resin cement (Panavia 21, Kuraray Medical).

Clinical examinations

Immediately after cementation of the crowns, the following parameters were assessed.
Biologic examinations
Biologic examinations included periodontal charting with periodontal probing depth (PPD), bleeding on probing (BOP), plaque control records (PCR), mucosal/gingival recession (REC), and width of the keratinized mucosa (KM). In addition, the thickness of the mucosa at the implant and control sites (contralateral tooth) was measured to the nearest 0.5 mm at a level 1 mm below the gingival/mucosal margin using an endodontic file.

Esthetic examination
The esthetic examination included measurements of the mucosal/gingival color with a spectrophotometer (Spectroshade, MHT), the papilla height, the Papilla Index, and the crown height (Fig 2).

Spectrophotometric assessments were performed 1 mm below the gingival/mucosal margin at the implant and the contralateral natural tooth sites. The implant site was evaluated prior to the insertion of the abutment, 5 to 10 minutes after placement of the abutment (prior to crown cementation), as soon as the blanching of the soft tissues disappeared, and 1 week after cementation of the crown. All color measurements were performed according to a previous publication. The calculated color differences (ΔE) included the following: implant site with abutment versus contralateral tooth and the implant site with cemented crown versus the contralateral tooth.

Fig 1 (a) Clinical case with two lateral incisors with zirconia abutments in situ: pink-veneered abutment in the maxillary left lateral incisor (study site) and white abutment at the maxillary right lateral incisor. (b) Pink-veneered abutments. (c) Control abutments.

Fig 2 Esthetic measurements: $D =$ distance from the highest line of gingival/mucosal curvature of the upper crown to the base of the tooth/implant (crown length) and $E =$ distance from the papilla tips to the incisal edge (papilla height).

Statistical analysis
All data were analyzed descriptively, calculating mean values and SDs. The biologic and esthetic outcomes for the test and control groups were compared using the Student t test. The level of significance chosen in all tests was $P < .05$. The analysis was performed using a statistical software program (Graphpad Prism, GraphPad Software).
Results

The implants in the test group replaced three incisors and seven premolars, while the implants in the control group replaced seven incisors and three premolars in the maxilla or mandible. For all 20 patients, the final reconstructions were incorporated. Figure 3 shows one patient from the test group. A clinical case from the control group is presented in Fig 4.

Biologic outcomes

All implants remained osseointegrated. No biologic complications were observed upon insertion of the final reconstruction. For an overview on all biologic outcome measures, see Table 1.

There were no significant differences between the test and control groups with respect to tissue thickness at the buccal aspect of the implants ($P > .05$). The tissue thickness was significantly thinner at the control teeth ($1.4 \pm 0.4 \text{ mm}$).
compared with implant sites (1.7 ± 0.6 mm) (P < .05). In the test group, the peri-implant mucosa was thinner than 2 mm in eight patients and equal to or greater than 2 mm in two patients. In the control group, five patients had a peri-implant mucosa thinner than 2 mm and five patients had a mucosa equal to or greater than 2 mm.

Esthetic examination

All esthetic data are presented in Tables 2 and 3. The nonrestored abutments induced a visible change in the color of the peri-implant mucosa compared with the contralateral natural teeth. The visible color change was higher for test (ΔE 6.4 ± 3.9) than for control abutments (ΔE 5.2 ± 2.9) (P > .05). The thickness of the mucosa, measuring less than 2 mm or equal to or greater than 2 mm, did not significantly influence the outcomes for the test and control groups (P > .05). After cementation of the crown, the calculated color differences compared to the natural control teeth reached ΔE of 6.3 ± 2.2 at test and
**Table 1**  
Biologic outcome measurements (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Test</th>
<th>P (control vs test)</th>
<th>Implant sites</th>
<th>Control teeth</th>
<th>P (implant vs tooth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPD (mm)</td>
<td>3.3 ± 0.8</td>
<td>3.5 ± 0.7</td>
<td>NS</td>
<td>3.4 ± 0.6</td>
<td>2.7 ± 0.5</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>BOP (%)</td>
<td>30 ± 48</td>
<td>40 ± 52</td>
<td>NS</td>
<td>35 ± 49</td>
<td>35 ± 49</td>
<td>NS</td>
</tr>
<tr>
<td>PCR (%)</td>
<td>30 ± 48</td>
<td>30 ± 48</td>
<td>NS</td>
<td>35 ± 49</td>
<td>45 ± 51</td>
<td>NS</td>
</tr>
<tr>
<td>REC (mm)</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>NS</td>
<td>0.0 ± 0.0</td>
<td>-0.1 ± 0.3</td>
<td>NS</td>
</tr>
<tr>
<td>KM (mm)</td>
<td>2.8 ± 1.0</td>
<td>2.8 ± 1.0</td>
<td>NS</td>
<td>3.0 ± 1.0</td>
<td>3.4 ± 0.8</td>
<td>NS</td>
</tr>
<tr>
<td>ThG (mm)</td>
<td>1.8 ± 0.7</td>
<td>1.6 ± 0.4</td>
<td>NS</td>
<td>1.7 ± 0.6</td>
<td>1.4 ± 0.4</td>
<td>.0387</td>
</tr>
</tbody>
</table>

PPD = periodontal probing depth; BOP = bleeding on probing; PCR = plaque control records; REC = recession; KM = width of keratinized gingiva/mucosa; ThG = soft tissue thickness; NS = not significant.

**Table 2**  
Esthetic outcome measurements (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>n</th>
<th>Test</th>
<th>n</th>
<th>P (control vs test)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>∆E abutment vs natural tooth (overall)</td>
<td>5.2 ± 2.9</td>
<td>10</td>
<td>6.4 ± 3.9</td>
<td>10</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>∆E mucosal thickness &lt; 2 mm</td>
<td>3.7 ± 1.5</td>
<td>5</td>
<td>5.6 ± 3.3</td>
<td>8</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>∆E mucosal thickness &gt; 2 mm</td>
<td>7.2 ± 3.2</td>
<td>5</td>
<td>9.3 ± 6.2</td>
<td>2</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>∆E crown vs natural tooth (overall)</td>
<td>4.6 ± 1.8</td>
<td>10</td>
<td>6.3 ± 2.2</td>
<td>10</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>∆E mucosal thickness &lt; 2 mm</td>
<td>4.2 ± 1.6</td>
<td>5</td>
<td>6.2 ± 1.9</td>
<td>8</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>∆E mucosal thickness &gt; 2 mm</td>
<td>4.9 ± 2.1</td>
<td>5</td>
<td>6.5 ± 4.6</td>
<td>2</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

∆E = color difference; NS = not significant.

**Table 3**  
Esthetic outcome measurements for L, a, and b values

<table>
<thead>
<tr>
<th>Group</th>
<th>Mucosal thickness (mm)</th>
<th>With abutment (mean ± SD)</th>
<th>Natural tooth (mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>Test</td>
<td>Overall</td>
<td>46.2 ± 7.0</td>
<td>24.0 ± 5.6</td>
<td>15.7 ± 3.2</td>
</tr>
<tr>
<td></td>
<td>&lt; 2</td>
<td>48.7 ± 3.3</td>
<td>22.0 ± 4.0</td>
<td>14.9 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>≥ 2</td>
<td>36.4 ± 11.2</td>
<td>32.2 ± 0.5</td>
<td>18.7 ± 5.5</td>
</tr>
<tr>
<td>Control</td>
<td>Overall</td>
<td>49.6 ± 5.0</td>
<td>26.9 ± 3.6</td>
<td>16.7 ± 1.8</td>
</tr>
<tr>
<td></td>
<td>&lt; 2</td>
<td>47.6 ± 6.2</td>
<td>26.8 ± 4.5</td>
<td>15.7 ± 1.9</td>
</tr>
<tr>
<td></td>
<td>≥ 2</td>
<td>52.2 ± 1.4</td>
<td>26.9 ± 3.0</td>
<td>17.9 ± 0.2</td>
</tr>
</tbody>
</table>

L = lightness of the mucosa; a = color-opponent dimension with a position between red/magenta and green; b = color-opponent dimension with a position between yellow and blue.

*Statistically significant.
4.6 ± 1.8 at control sites (P > .05). Similar to the nonrestored abutments, the thickness of the mucosa had no significant influence on color changes (P > .05) (Table 2). In contrast to the ΔE values, the mean lightness (mean L values) of the mucosa around nonrestored abutments was significantly lower in the test group compared to the lightness of the gingiva of contralateral natural teeth (P < .05). This decrease was dependent on soft tissue thickness and was significantly more pronounced at thin soft tissues (< 2 mm) (P < .05). The comparisons of the color parameters a (color-opponent dimension with a position between red/magenta and green) and b (color-opponent dimension with a position between yellow and blue) between implant sites and natural teeth in the test and control group showed no statistically significant differences (P > .05) (Table 3).

Discussion

The present study investigated the impact of color modifications of the submucosal part of zirconia abutments on color changes of the peri-implant mucosa. The outcomes of the study demonstrated that both the test (pink-veneered) and control zirconia (white original) abutments induced visible discoloration of the peri-implant mucosa compared with the gingiva of natural teeth. The discoloration was more pronounced in the pink-veneered group than in the white control group. In addition, the abutments veneered with the pink ceramic led to a decrease of the lightness (mean L) of the mucosa, specifically at sites with a mucosal thickness of less than 2 mm. Based on the scientific literature, two main parameters influence the color of the peri-implant tissue: the soft tissue thickness and the abutment material.4,8 The soft tissue thickness depends on the biotype of the mucosa26 and is therefore given at the beginning of the prosthetic phase. At this timepoint, the abutment as part of the final reconstruction offers further options to optimize the esthetic outcome.13 In the past, metal abutments were preferable but can cause a grayish discoloration of the peri-implant mucosa.8,27 More recently, various ceramics were introduced for implant abutments, with zirconia being the most promising material. Even though the discoloration of the mucosa caused by zirconia abutments appeared to be reduced compared with metal abutments, clinically visible color differences have been reported in posterior and anterior implant sites.7,8 This observation was confirmed in the present study, with control sites demonstrating mean ΔE values above the clinically visible threshold value of 3.7.28 To overcome these issues with the discoloration of the peri-implant tissue, various studies tried to identify an optimal color for the transmucosal part of implant reconstructions.27,29,30 In a clinical study, the optical effect of color strips was analyzed after placing them in peri-implant mucosa sites. Light pink, pink, light orange, and orange strips appeared to be esthetically more favorable compared with white abutments.18,27 Hence, a modification of the color of white zirconia abutments should result in more favorable esthetic outcomes.31 Based on this assumption, white zirconia plates were veneered with different pink-colored veneering ceramics in the present study. These modified zirconia plates were then evaluated for color match to the gingiva of natural teeth using a spectrophotometer (unpublished data, 2014). The ceramic material with the best color match was then chosen and used as a veneering ceramic for the submucosal part of white zirconia abutments in the present clinical study. However, the modified zirconia abutments demonstrated an even higher discoloration of the peri-implant mucosa compared with white abutments and therefore failed to be more favorable from an esthetic point of view. Two reasons may explain why in both the test and

Papilla Index

The Papilla Index25 revealed no significant differences between test and control groups (P > .05), while the differences between implant sites (1.9 ± 0.8) and natural control teeth (2.4 ± 0.7) were statistically significant (P < .0001). Similar observations were made with respect to the papilla height, revealing no differences between the test and control groups (P > .05). The papilla height was higher around teeth (3.2 ± 1.3 mm) compared with implant sites (2.9 ± 1.3 mm), revealing statistically significant differences (P < .0001).
control groups, the discoloration of the mucosa was above the clinically visible threshold value: (1) the brightness and translucency of the chosen pink ceramic material, and (2) the thickness of the mucosa. First, a highly translucent pink ceramic was chosen as veneering material. It is speculated that because of the high translucency, the color reflection from the abutment was kept on a rather low level, therefore decreasing the brightness and leading to a grayish discoloration of the mucosa. This observation is supported by the mean L values being statistically significantly lower in the test group with a thin mucosa and by a recently published case series.\textsuperscript{31} In that study, the color differences between implant sites and natural teeth were below the threshold value (3.7) in almost half of patients. It was concluded that the brightness obtained through the fluorescent ceramic appeared to be more adapted to the natural gingiva. This underlines that the color of the peri-implant tissue is affected by various parameters including the translucency and brightness of the reconstruction material. Second, the soft tissue thickness on the buccal side of teeth and implants is known to be different.\textsuperscript{8,32,23} It is generally accepted that the thickness of the buccal soft tissue can in part control the color of the peri-implant mucosa. Indeed, no statistically significant influence of the mucosal thickness was found with respect to the esthetic outcomes. This is in agreement with a multicenter study with a similar number of patients\textsuperscript{20} that demonstrated no statistical correlation between soft tissue thickness and degree of discoloration.\textsuperscript{17} In that study, gold, titanium, and zirconia abutments were evaluated using a spectrophotometer. The thickness of the mucosa was assessed at the level of the implant shoulder.\textsuperscript{17} This is slightly below the level measured in the present study (1 mm below the mucosal margin). An assumption can be made that the lack of correlation may also be due to an unequally balanced number of patients and sites presenting with a thick (> 2 mm) and thin (< 2 mm) mucosa in the test and control groups. In the test group, only 7 implant sites had a thickness of more than 2 mm, while in the control group, the respective number of implants amounted to 13. Due to this inhomogeneity, a confounding effect of the tissue thickness cannot be neglected.

Conclusion

Veneering the submucosal part of white zirconia abutments using pink ceramics failed to positively influence the esthetic outcome in the present study. Further efforts need to be undertaken to increase L values of modified zirconia abutments to minimize the soft tissue discoloration at implant sites independent of the soft tissue thickness.

Acknowledgments

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