A Longitudinal Clinical Study of Procera Ceramic-Veneered Titanium Copings

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Purpose: The purpose of the present paper was to study the long-term clinical results with ceramic-veneered Procera titanium copings. 

Materials and Methods: A total of 44 titanium copings (fabricated for 22 patients) veneered with a low-fusing ceramic were followed for 60 to 78 months. The clinical examinations were performed by licensed specialists in prosthetic dentistry. The crowns were rated according to the California Dental Association system. In addition, Bleeding Index and Margin Index were also evaluated. 

Results: In 3 crowns ceramic fractures necessitated their replacement. Two crowns had to be replaced because of caries. The ratings for surface and color had changed markedly, from excellent to acceptable. Regarding anatomic form, with the exception of the 3 fractured ceramic crowns, there were no obvious changes. The margin integrity, aside from the 2 crowned teeth with caries, was recorded as satisfactory (excellent or acceptable) for all other crowns; in fact, a large majority were rated excellent. Regarding Bleeding Index, there were no differences between crowned teeth and control teeth. Changes in Margin Index showed that the gingiva of the crowned teeth had retracted. 

Conclusion: Of the various clinical factors evaluated, only surface and color—related to the low-fusing ceramic used for veneering—showed any obvious change during the follow-up period. Otherwise the veneered titanium copings had, in general, performed well. Int J Prosthodont 1999;12:135-139.

Unalloyed titanium is inexpensive and its excellent biocompatibility is well documented. It has been used for 10 to 15 years in fixed prosthetics. The 2 most commonly used fabrication methods for crowns and fixed partial dentures are casting (see review by Hamanaka) and a combination of machine duplication and spark erosion—the Procera method (Nobel Biocare). The clinical performance of cast titanium restorations has been reported, for example, by Tani, Kawazoe, and Kaus et al. Regarding the fit of titanium cast crowns and inlays, Tani suggested that the precision of titanium restorations was somewhat inferior to that of noble alloy prostheses but far superior to the fit of Ni-Cr alloy prostheses. Kawazoe published results consistent with those of Tani. Kaus et al reported that among ceramic-veneered titanium restorations followed for 21 to 41 months there was a significantly higher survival probability for single crowns than for fixed partial dentures. The clinical results for cast titanium restorations published to date are of a short-term character. Several clinical studies have been presented for copings fabricated with the Procera method, some in which composite materials were used for the veneering and some using low-fusing ceramics.
require the use of a low-fusing ceramic for veneering. Composites used as a veneering material have shown some obvious shortcomings in the long run; thus, low-fusing ceramics tend to predominate today. Generally the clinical results with ceramic-veneered Procera titanium copings have been satisfactory. However, the follow-up periods in the studies cited above have been comparatively short, varying from 12 to 30 months. In an earlier paper by the authors, the clinical results of Procera-fabricated titanium copings veneered with Procera Ceramic, a low-fusing ceramic, were presented after a period varying between 26 and 30 months. Evaluations according to California Dental Association (CDA) criteria showed that the rating for surface and color had changed markedly, from excellent to acceptable. For the factor anatomic form there was a small shift from excellent to acceptable. The third factor, margin integrity-related entirely to the marginal fit between the titanium coping and the tooth preparation—was recorded as satisfactory (excellent or acceptable) for all artificial crowns; in fact, a large majority were rated excellent.

As pointed out by Boening et al., long-term studies are needed to determine whether the titanium-ceramic bond is strong enough to sustain the demands of clinical conditions. Furthermore, any ceramic fracture resulting from static fatigue cannot be expected to appear until after a prolonged period of time. This was one motivation for a reexamination of the patient material presented earlier. The authors were also interested in evaluating whether further changes in the surface and color of the ceramic material had taken place after the first 26 to 30 months. It was therefore decided to recall the patients for examination after a lapse of at least 5 years from insertion of the crowns. The present paper reports clinical findings after a period ranging from 60 to 78 months.

**Materials and Methods**

In 1989, 47 crowns were fabricated for 24 patients. The patients were treated by 5 dentists, 4 working in the Public Dental Health Service and 1 in private practice. The patient material consisted of 14 women and 10 men with a mean age of 47.8 years, range 30 to 67 years. The crowns were first examined shortly after cementation (baseline). The first reexamination took place after 14 to 18 months (Re-ex I), the second after 26 to 30 months (Re-ex II), and the third, presented in this paper, after 60 to 78 months (Re-ex III).

Two of the patients present at baseline registration could not attend Re-ex III. One man with a crown in the mandibular molar area had moved abroad and a woman with one crown each in the mandibular premolar and molar areas was working in a distant region of Sweden. One patient could not be examined at Re-ex II because of illness took part in Re-ex III. These facts make direct comparisons impossible for all patients between baseline and Re-ex I, II, and III, respectively. It was therefore decided to compare the results of those crowns that could be rated both at baseline and at Re-ex III. Thus, this paper presents the results for 22 patients with 44 crowns. It should be noted that neither of the remaining 2 patients reported any problems with their crowns.

The clinical examinations were performed by licensed specialists in prosthetic dentistry. The crowns were rated according to the CDA system. In addition, Bleeding Index and Margin Index were evaluated. Details of materials and methods were presented in the previous paper by the authors.

**Results**

In 2 patients caries contiguous with the margin of the titanium coping necessitated the substitution of new crowns for the originals. One post and core had fractured at Re-ex II. It had been constructed using a brass screw as the post and glass-ionomer cement for the core. Neither the tooth itself nor the crown showed any defect. A new post and core was adapted to the existing crown and tooth and cemented. This crown is included in the present study.

**CDA Ratings**

There was a marked change in the factor surface and color at Re-ex III; it shifted from excellent to acceptable (Table 1). The surfaces that changed had become slightly rough or pitted but were still polishable. Two crowns with ceramic fractures had required replacement after 18 and 26 months, respectively, because of the amount of material lost. At Re-ex III it was established that another crown had to be replaced for the same reason. Three crowns were thus rated as not acceptable.

Regarding anatomic form there was no obvious change, aside from the 3 crowns with ceramic fractures reported above (Table 1). Some small changes were noted for margin integrity (Table 1). At Re-ex III this factor was recorded as satisfactory in all but 2 cases in which, as mentioned above, caries necessitated
Table 1  Evaluation of Crowns in Accordance with CDA Characteristics (n = 44)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Exam</th>
<th>Excellent</th>
<th>Acceptable</th>
<th>Replaced/replace statin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface and color</td>
<td>Baseline</td>
<td>31</td>
<td>13</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Re-ex III</td>
<td>16</td>
<td>25</td>
<td>3*</td>
</tr>
<tr>
<td>Anatomic form</td>
<td>Baseline</td>
<td>29</td>
<td>15</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Re-ex III</td>
<td>31</td>
<td>10</td>
<td>3*</td>
</tr>
<tr>
<td>Margin integrity</td>
<td>Baseline</td>
<td>43</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Re-ex III</td>
<td>58</td>
<td>4</td>
<td>2*</td>
</tr>
</tbody>
</table>

*Two crowns had been replaced after 18 and 26 months, respectively, and one had to be replaced after Re-ex III.

Two crowns had to be replaced at Re-ex III because of caries.

Baseline = shortly after cementation; Re-ex III = 60 to 78 months after cementation.

Table 2  Bleeding Index (%) Recorded in Accordance with Lenox and Kopczyk17 for the 44 Teeth with Titanium/Ceramic Crowns and the 44 Control Teeth

<table>
<thead>
<tr>
<th></th>
<th>Mesial</th>
<th>Buccal</th>
<th>Distal</th>
<th>Lingual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>C</td>
<td>T</td>
<td>C</td>
</tr>
<tr>
<td>Baseline</td>
<td>25</td>
<td>30</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Re-ex III</td>
<td>59</td>
<td>66</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

T = teeth with titanium/ceramic crowns; C = control teeth; Baseline = shortly after cementation; Re-ex III = 60 to 78 months after cementation.

Table 3  Margin Index by Percent of Surfaces Recorded in Accordance with Silness18 for the 44 Crowns Examined

<table>
<thead>
<tr>
<th>Margin Index</th>
<th>Baseline</th>
<th>Re-ex III</th>
<th>Baseline</th>
<th>Re-ex III</th>
<th>Baseline</th>
<th>Re-ex III</th>
<th>Baseline</th>
<th>Re-ex III</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>11</td>
<td>34</td>
<td>2</td>
<td>5</td>
<td>11</td>
<td>32</td>
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<tr>
<td>2</td>
<td>18</td>
<td>23</td>
<td>68</td>
<td>41</td>
<td>7</td>
<td>18</td>
<td>66</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>72</td>
<td>21</td>
<td>20</td>
<td>91</td>
<td>75</td>
<td>23</td>
<td>27</td>
</tr>
</tbody>
</table>

Baseline = shortly after cementation; Re-ex III = 60 to 78 months after cementation; 0 = restoration margin more than 2 mm above the gingival margin; 1 = restoration margin less than 2 mm above the gingival margin; 2 = restoration margin level with the gingival margin; 3 = restoration margin below the gingival margin.

their replacement with new crowns. The majority were still classified as excellent. In the 4 cases rated as acceptable there was visible evidence of slight marginal discrepancy but no evidence of decay, and no repair was judged necessary. Consequently, 5 out of 44 crowns had been replaced or had to be replaced because of caries or ceramic fracture. This represents a failure rate after 60 to 78 months of 11%.

Bleeding Index

The Bleeding Index (Table 2) had increased at Re-ex III at the approximal and lingual sites in both restored teeth and control teeth, and also in control teeth buccally.

Margin Index

Mesially there were no obvious changes in Margin Index, but both buccally and lingually the ratings showed retractions of the gingiva, as reflected by a substantial change, from grade 2 to 1. A similar tendency was seen distally (Table 3).

Discussion

The number of patients in the present study is certainly limited. However, all of the initial 24 patients could be traced and accounted for. The 2 patients who could not attend Re-ex III did not report any problem with their crowns. The risk of selection bias because of absentees is thus eliminated.
and there is reason to assume that the results obtained in the present study are representative of ceramic-veneered titanium copings fabricated with the Procera method in the late 1980s.

Margin integrity was satisfactory in all but 2 crowns. It was rated excellent in 86% of the crowns, compared to 98% at the baseline examination. In 4 crowns the margin integrity was classified as acceptable, an increase of 3 during the follow-up period. One explanation for this change may be the dissolution over time of cement at the crown margin, which revealed a discrepancy between the titanium coping and the tooth that was undetectable at the baseline examination or at Re-ex 1 or II. The same explanation may also be valid for the 2 crowns that had to be replaced because of caries detected at Re-ex III. Discrepancies arising between the titanium coping and tooth substance may have made it easier for caries risk factors to exert their detrimental influence on the tooth substance. However, caries may have attacked the tooth substance despite the originally excellent marginal fit of the copings, with the consequence that the margin integrity was classified as unacceptable at Re-ex III. The percentage of crowned teeth attacked by caries during the follow-up period of 5 to 6.5 years, 5%, is comparatively low.

The CDA rating of excellent regarding margin integrity of single crowns fabricated with the Procera method was substantially higher in the present study after 5 to 6.5 years than that reported after 1 year by Chai et al and after 2 years by Smedberg et al. However, it is close to that reported by Lövgren et al after 1 year. The present long-term study has shown that the method used for fabrication of the titanium copings has great potential for obtaining a good marginal fit when, as in the present study, a chamfer or feather-edge tooth preparation is used. Boening et al, however, reported less satisfactory results with a shoulder preparation.

Both crown-restored teeth and control teeth had an increased Bleeding Index during the follow-up period. This increase may be a result of neglect of oral hygiene; the close correlation between plaque accumulation and gingivitis is notorious. The fact that the crowned teeth did not show a greater increase than the control teeth may reflect the very good marginal fit of the titanium copings discussed above.

Buccally and lingually the Margin Index indicated that the gingiva of the crowned teeth had retracted. It is not easy to interpret this result, as the retraction of gingiva can be caused by several factors. However, the very good fit of the titanium copings probably at least contributed to the prevention of inflammatory hypertrophy of the gingiva. It is well known that this phenomenon may be directly or indirectly caused by deficient marginal adaptation between a restoration and the tooth substance.

In our previous study we found no change for surface and color between baseline and Re-ex I after 14 to 18 months. This short-term result agrees well with the 1-year results of both Chai et al and Lövgren et al. However, at Re-ex II after 26 to 30 months a marked change, from excellent to acceptable, had occurred. This change was even more pronounced after 60 to 78 months at Re-ex III. These observations are in line with those of Reppel et al and Smedberg et al. The results strengthen Jones's vitro-based hypothesis that low-fusing ceramics have less chemical stability in a biologic environment than medium-fusing ceramics. It should be noted that the Procera ceramic used in the present study was from the first generation of low-fusing ceramics. With the use of later generations of these low-fusing ceramics, different results may be obtained.

A total of 3 crowns had to be replaced because of extensive ceramic fractures. The present failure rate, 7%, is somewhat higher than that reported for some other combinations of metal alloys and ceramics, but it is considerably lower than that presented by Schmidt. As discussed in our earlier paper, one reason for the occurrence of the ceramic fractures may be that at the time the titanium copings were fabricated, their outer surfaces were not individually designed, but were shaped like a thimble. This resulted in large differences in the thickness of the ceramic layer in various parts of the crown and difficulties in evaluating stress distribution. Currently, the surfaces of titanium copings to be veneered are designed individually with computer assistance to enable optimization of the thickness of the ceramic material. This should decrease the risk of ceramic fractures.

It is obvious that direct comparisons between various studies regarding a specific treatment method are complicated for many reasons. Therefore, the authors have initiated a clinical study with intrindividul comparisons between titanium copings veneered with a low-fusing ceramic and a conventional type of metal-ceramic crown with a medium-fusing ceramic. In such a study valid comparisons can be made with regard to all of the factors that were analyzed in the present study.

Conclusion

A total of 44 titanium copings (fabricated for 22 patients) veneered with a low-fusing ceramic were
followed for 60 to 78 months. The crowns were rated according to the CDA system. In addition, Bleeding Index and Margin Index were evaluated. Of the clinical factors evaluated, only surface and color—related to the low-fusing ceramic used for veneering—showed any obvious change during the follow-up period. Otherwise the veneered titanium copings had, in general, performed well.

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References
