Clinical and laboratory evaluation of CAD/CAM All-ceramic crowns
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CHAPTER 6

Two-year Clinical Evaluation of All-Ceramic Crowns Made by Two Different CAD/CAM Systems

Catherine C. Begazo, Marinus A.J. van Waas and Albert J. Feilzer. Two-year clinical evaluation of all-ceramic crowns made by two different CAD/CAM systems. Submitted for publication.
Abstract

Purpose: The aim of this prospective study was to evaluate and compare the clinical behavior of all-ceramic crowns fabricated partially by two different CAD/CAM systems.

Materials and Methods: 94 all-ceramic anterior and posterior crowns were placed in 42 patients in a dental practice. Two different CAD/CAM systems made the copings of the crowns (46 Procera AllCeram and 48 CICERO copings). A general dental practitioner treated all patients and a dentist not involved with the treatment evaluated the crowns after a period of two years. The California Dental Association quality evaluation system was used for the clinical evaluation. X-rays, stone models and intra-oral photographs were also registered. The patients were requested to fill in a form with his/her personal opinion about the crown.

Results: The marginal integrity was assessed excellent or acceptable for 92% of the crowns. The color was assessed excellent for 91% of the crowns according to the evaluator; the patients scored a higher level of satisfaction. Endodontic treatment was not performed in any tooth after the cementation. Gingival condition did not change after the cementation of the crowns.

Conclusions: The clinical evaluation shows a similar clinical behavior and indicates a good prognosis for both CAD/CAM systems. The crowns based on Procera AllCeram and CICERO CAD/CAM aluminum oxide copings are applicable to all areas of the mouth during the first two years of use. This is particularly true in view of the very high patient satisfaction.
Introduction

An increasing demand of tooth-colored, aesthetic restorations for restoring decayed teeth is recognized. For the creation of more comprehensive restorations, the porcelain fused to metal restoration was for a long time the best option to create a tooth-colored and aesthetic restoration. Dental ceramics are highly appreciated for their properties as biocompatibility, optimal aesthetics, low plaque accumulation, low thermal conductivity, high abrasion resistance and high color stability\(^1\),\(^2\). However, when used in porcelain fused to metal restoration, the metal base forms one of the main drawbacks as, beside the fact that precious metals are costly, they lack transparency, which makes the imitation of the natural transparent hard tooth tissues a demanding task for the dental technician. As a consequence, many manufacturers and researchers tried to develop metal-free restorative materials for the production of all-ceramic restorations\(^3\).

With the introduction of Cerestore in 1983 (Coors Biomedical) the use of all-ceramic crowns for restoring posterior teeth was realized for the first time. This all-ceramic system was based on a complicated laboratory procedure to produce a ‘strong’ coping from a special ceramic, containing 60% alumina. Finally this product was withdrawn from the market since the clinical performance of posterior crowns did not meet the expectations claimed by the manufacturer\(^4\). As a consequence the search into stronger core ceramics had to be continued, leading to the development of new ceramic materials. Two directions of development can be recognized: materials that are aimed to be used for the production of the whole restoration manually at the dental technicians office and a direction that is based on production techniques that require high precision, therefore they are mainly CAD/CAM based\(^5\). The latter direction could be divided again into systems that are based on half-products which are produced by CAD/CAM in a central production laboratory or in half-products that can be produced by CAD/CAM in the dental technician’s own office.

Nowadays, CAD/CAM has a firmly established role in many aspects of clinical dentistry. More than twenty years have passed since investigations of this technology’s application in the field of dentistry had begun\(^6\). Traditional methods, such as making the impression, pouring the cast, waxing, and casting, remain rather fundamental. Dental CAD/CAM offers an extraordinary opportunity to introduce into
dentistry the most modern techniques from physical science and mathematics. Also CAD/CAM allows the use of materials that cannot be used with conventional dental processing techniques. Recently the scope, sophistication and number of systems have increased.

This study aimed to compare the clinical behavior of all-ceramic crowns made on strong copings that are produced by two different CAD/CAM systems and materials. Since 1988 a research group in the Netherlands has been working on the development of a new dental CAD/CAM platform for Computer-Integrated Ceramic Reconstruction (CICERO) for the fabrication of all-ceramic restorations with consecutive layers of a shaded high-strength aluminum-based core material. The copings are made of a reinforced glass ceramic, which contains 66% aluminoxide, 20% siliciumoxide and 14% others (Synthoceram, Elephant Dental, B.V., the Netherlands). In 1993 Procera (Nobelpharma, Sweden) presented the AllCeram crowns consisting of a densely sintered 99.9% alumina core with baked-on dental porcelain. Moreover, due to the different compositions, the production procedure of both systems differs too. Using the Procera AllCeram process for copy milling, an enlarged model of the original die is manufactured; alumina powder is compacted onto the enlarged die under high pressure and then sintered to full density. CICERO copings are baked on milled copies of the preparation made from investment material without enlargement. It was hypothesized that CICERO's approach might result into the production of more predictable and accurate restorations and therefore they would perform clinically better.

Materials and Methods

This prospective clinical study evaluated and compared the performance of 94 all-ceramic crowns; the ceramic copings of these crowns were produced by two different CAD/CAM systems, Procera AllCeram and CICERO. The medical ethical committee of the university hospital of the University of Amsterdam approved the study.

Patient selection

In April 2000, patients of a general dental practice who needed individual fixed prosthodontic restorations were selected and invited to participate on this clinical study. They received a brief description of the CAD/CAM techniques from Procera
and absence of antagonist were excluded from this study. Written informed consent was obtained. When it was possible, a split mouth concept was applied. In this way forty-four patients, 30 women and 14 men (mean age 38 years, range 23 to 65 years) participated. The distribution of the sample is presented in Table 1.

**Preparation and crown production procedure**

The dentist made preparations according to the guidelines of the manufacturer. Forty-six Procera AllCeram copings and forty-eight CICERO copings were made. CICERO preparation guidelines prescribe a shoulder angle between $90^\circ$ – $130^\circ$, a shoulder width between 0.7 – 1.2 mm and an occlusal reduction between 1.5 – 2.0 mm with encompassing rounded inner edges. The outline must be clearly recognizable, enabling automatical definition of preparation outline by the software of the system. Procera AllCeram prescribes a deep-chamfer of 0.8 mm (minimum) and an occlusal preparation depth of 1.5 mm (minimum).

Once the tooth preparation was completed, impressions were made using Impregum (3M-Espe, Seefeld, Germany) and poured in stone (Fuji Rock, GC Japan). The copings were fabricated at their respective central production laboratory, at NobelPharma, Sweden and at CICERO Central Lab, the Netherlands. The complete Procera AllCeram$^9,10,11,12$ and CICERO$^{13,14,15,16}$ CAD/CAM procedures are extendedly described in the literature; therefore they are not repeated in this article.

Finally the copings were veneered with ceramic porcelain (Sintagon, Elephant Dental B.V., the Netherlands) in accordance with the recommended procedure of the manufacturer, after that they were sent to the dental practice. After checking the fit, the crowns were luted with glass-ionomer cement (GC Fuji I, GC Corporation, Tokyo, Japan).

**Clinical evaluation**

At the initial stage of the study (April 2000), a dentist not involved with the patient’s rehabilitation treatment evaluated the oral cavity of the patients selected. An intake clinic evaluation, periapical x-rays, gingival condition, stone models and intra-oral photographs were made.

After a two-year period, the same dentist evaluated the CAD/CAM crowns by means of a clinical evaluation form, periapical x-rays, gingival condition, stone models and intra-oral photographs at occlusal and buccal views. The intra-oral
photographs and stone models were used as documentation. Finally each patient filled in a subjective questionnaire with his/her opinion of the CAD/CAM crowns.

For the clinical evaluation a modified version of the California Dental Association (CDA) criteria was used. To score the color, each crown was evaluated in three independent areas, cervical, buccal and occlusal.

The radiographic evaluation was based on the comparison between the periapical x-rays taken at the initial stage (April 2000) and the ones taken after two years. Two evaluators, working independently, compared and assessed each x-ray. When the ratings differed the evaluators resolved their disagreement by joint examination. The items of the evaluation were: tooth endodontically treated 'yes' or 'no', tooth reconstructed by endodontic post 'yes' or 'no' and periapical condition of the tooth. When a homogeneous periodontal ligament space could be recognized at the peri-apex the radiological condition was recorded as healthy, while a round peri-apical radiolucency of less than 2 mm diameter was recorded as questionable and periapical radiolucency larger than 2 mm diameter was recorded as unhealthy.

At last every patient was requested to fill in a questionnaire to reveal his/her opinion about the crowns. The questionnaire involved questions about general satisfaction, color, shape and comfort. These items were scored 1 to 5. Questions about the sensibility to cold and warm and about pain were asked too. These items were scored 1 to 4.

Results

Ninety-one crowns (97%) in 42 of 44 patients (29 women, 13 men) were examined by one of the authors two years after the crown has been placed. Two patients did not show up for examination in spite of two or more reminders.

Minor fractures within the dental porcelain were recorded for five crowns, three Procerca AllCeram and two CICERO (6.6% and 4.3% respectively). The patients did not notice when it occurred. These five crowns were polished and continued functioning without problems.

Five crowns (5.4%), four (8.8%) Procerca AllCeram and one (2.1%) CICERO had come loose. All of them could be recemented successfully. Glass-ionomer cement (GC Fuji I, GC Corporation, Tokyo, Japan) was used for recementing these crowns.
In the assessment of marginal integrity, 92% of the crowns were considered excellent or acceptable (37% excellent, 55% acceptable). Five crowns (5.4%), two (4.4%) Procera AllCeram and three (6.5%) CICERO crowns were rated as overcontoured and two (2.1%) of them, one of each system, presented a distobuccal micro gap. No caries was recorded.

According to the clinician's evaluation in 91% of the cases the crowns were assessed as having excellent aesthetics. Eight crowns (8.5%) four crowns of each system, presented a mismatch at the cervical area. The patients did not notice the mismatch and they considered the crowns with excellent aesthetic.

Thirty-two (34%) teeth were already endodontically treated when the selection of the patients started. Ten of these teeth were reinforced with a metal cast post. Lately eight (8.5%) teeth selected for this study needed an endodontic treatment, which was successfully carried out by a specialist. No endodontic treatment was performed after the cementation of the crowns. No changes in the gingival conditions were recorded.

Table 1. Distribution (n) of Procera AllCeram and CICERO crowns at cementation and follow-up examination.

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Procera AllCeram</th>
<th>CICERO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incisor</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Canine</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Premolar</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Molar</td>
<td>27</td>
<td>27</td>
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<tr>
<td>Total</td>
<td>46</td>
<td>48</td>
</tr>
</tbody>
</table>

Discussion

This study was carried out to reveal whether two different CAD/CAM approaches for making strong copings for all-ceramic crowns would behave clinically successful. However, for the judgment of a system being clinically acceptable, the results of a clinical study should be viewed from different perspectives. For instance from the perspective of the expected brittleness of all ceramic crowns, the observation that crowns that were definitively cemented and became loose were not
damaged in such a way that they could not be recemented is unexpected. The incidence of 5.3% crowns that became loose within the first two-years is relatively high. Probably when cements with better adhesive properties to ceramic would be used this value may improve. On the other hand the use of cement with low adhesive properties to ceramic materials gives a clearer image of the intrinsic strength of the new ceramic materials used in this study. No reinforcing effect could be achieved due to its ability to integrate the restorative interfaces.

The strong coping material did not fracture during the observation period. However, during the observation period five crowns, three Procera AllCeram and two CICERO (6.6% and 4.3% respectively) showed small fractures of the veneering porcelain. It is difficult to decide whether this finding can be interpreted as early failure or not. Ceramic materials are prone to fail due to fatigue loading. Polishing of rough (fractured) surfaces will have a reinforcing effect\textsuperscript{17}. In cases where the dentist does not periodically check the patient's dental health, these small fractures might develop to larger ones causing final failure.

With regard to marginal gap width two crowns of each system were scaled as having marginal openings. As both systems make use of scans of poured gypsum dies it is not possible to reveal whether this result is caused by improper impression procedures, errors during preparation of the gypsum die or limitations of the CAD/CAM production system. Nevertheless, one should keep in mind the extremely low values of required cement film thickness originate from the use of the soluble zincoxyphosphate cements. Nowadays we are using much less soluble cements, which do not require such small values of cement film thickness. Therefore mainly aesthetic requirements remain for aiming for invisible crown margins. From that perspective the opaqueness of both coping materials limits the aesthetics, as it results in not optimal aesthetics of the crown margins.

Conclusions

Forty-six Procera AllCeram and forty-eight CICERO crowns were manufactured and cemented on molars, premolars and incisors in 44 patients and evaluated after two years with CDA criteria. Within the limits of this study, the following conclusions were drawn.

1. Of the 45 Procera AllCeram crowns followed after two years, 3 of the crowns (6.6%) experienced fractures that involved the veneering porcelain.
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2. Of the 46 CICERO crowns followed after two years, 2 of the crowns (4.3%) experienced fractures that involved the veneering porcelain.

3. None of the CAD/CAM aluminum oxide copings experienced fractures.

4. The clinical results indicate that both systems are suited for anterior as well as posterior crowns.

5. According to the questionnaire, all patients were satisfied or very satisfied with their all-ceramic restorations.

References


