

# A clinical examination of ceramic (Cerec®) inlays

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Two hundred and five Cerec® ceramic inlays placed by 8 dentists in 72 patients were examined independently by 3 calibrated evaluators 12-24 months after insertion, using the criteria of the California Dental Association (CDA) and also certain periodontal variables. Proximal dental plaque and bleeding on probing were not seen more often on Cerec surfaces than on control homologous surfaces. Ten patients reported postoperative sensitivity after treatment with Cerec inlays. Excellent CDA ratings for Color and Surface were obtained in 57% and 26%, respectively, and for Anatomic Form and Margin Integrity in 55% and 83%, respectively. Obvious differences were seen among the participating dentists with regard to the clinical quality of Cerec inlays. At present, the long-term performance of the Cerec technique cannot be predicted. □ CAD/CAM; ceramic inlays; Cerec® inlays

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The rapid development in the art and science of dental ceramics, in combination with factors such as an increasing demand for esthetically pleasing restorations and a certain mercury scare among several people, has extended the limits for the use of dental ceramics (1, 2). However, until the middle of the eighties ceramic restorations were almost exclusively luted with zinc phosphate cement, and it was not until the adhesive cementation technique was introduced that ceramic inlays for posterior restorations were more frequently used.

During the last few years several new materials and techniques for making ceramic inlays have been introduced onto the market. Well-known examples are castable glass ceramics, such as Dicor® (Dentsply International, Inc., York, Pa., USA) and Empress® (Ivoclar AG, Schaan, Liechtenstein) together with ceramics such as HiCeram® (Vita Zahnfabrik, Säckingen, Germany) and Mirage® (Myron International Inc., Kansas City, USA), which are merely technologic refinements of traditional porcelain systems. Inlays made of these and several other brands of dental ceramics are produced by an indirect technique

with dissimilar laboratory methods utilizing impressions and dies.

However, today it is also possible to make ceramic inlays in a direct way, in one sitting, using the CAD-CAM technique. At the beginning of the eighties a direct chairside CAD-CAM system for use in dentistry was developed by Mörmann & Brandestini (3-5). This system, called the Cerec® system (Siemens AG, Bensheim, Germany) was introduced onto the market in 1988 and is still the only commercially available CAD-CAM system for dental restorations.

The Cerec equipment uses a miniature videocamera with a CCD sensor with 256 × 256 pixels for the 'optical impression'. A picture of the cavity is taken, and a striation pattern is projected on the cavity. Depth information is obtained from the depth-related distortion of this striation pattern. The image acquired of the prepared tooth is recorded by the computer, and a picture of the tooth is displayed on a monitor. Recorded data about the tooth are used by the operator, interactively with the computer, to design the ceramic restoration on the monitor. This restoration—that is, the inlay/onlay—is then automatically produced

from a prefabricated block in the small three-dimensional CNC milling machine that is part of the equipment (6).

Apart from the obvious advantages of being able to make a ceramic inlay in one sitting there are other advantages, which are related to the quality of the material. Since the ceramic blocks are prefabricated under optimum and controlled conditions, it is possible to obtain a high and uniform quality without the inevitable material variations seen in manually produced restorations.

There are several ongoing systematic longitudinal studies on the clinical performance of so-called Cerec inlays at present (7). Apart from these studies, which in many cases are carried out by specialists at university clinics, it would be of interest to evaluate the quality of Cerec inlays done by dentists in general practice. The aim of the present study, therefore, was to examine several Cerec inlays, in situ for 12–24 months, done by general practitioners.

## Materials and methods

Eight dentists from four different geographic regions in Sweden were questioned about their Cerec inlay production. The dentists, of whom seven were private practitioners and one worked in the National Dental Health Service, had been working with the Cerec system for more than 1 year. They were asked whether they would agree to having their patients who had had Cerec

inlays for at least 1 year to participate in the study. As a result, 72 patients with a total of 205 Cerec inlays were examined. Since all the dentists participating had attended a clinical Cerec training course, approved by Siemens AG (Bensheim, Germany), the manufacturer of the equipment, it was presumed that the manufacturer's instructions and recommendations regarding clinical and technical procedures were followed.

The mean and median ages of the 43 female patients were 41 and 38 years, respectively (range 22–65 years), and of the 29 men 40 and 42 years, respectively (range, 14–57 years).

All the inlays/onlays were machined from prefabricated feldspathic ceramic blocks of the type Vita Cerec® Mk I or Mk II (Vita Zahnfabrik, Säckingen, Germany). Vita Mk II, which is a development of Mk I, is said to have a finer structure.

Information about design and manufacturing technique (designed from information obtained from the tooth cavity *per se* = direct; designed from a replica of the tooth cavity = indirect) and polishing technique was obtained from patient records and/or direct questioning of the dentists. The estimated overall time consumption including all steps in the production of a single Cerec inlay and the complications during and after the placement were reported by each dentist. In addition to routine anamnestic records the patients were asked why they had been treated with Cerec inlay/onlays.

Table 1. Number and age of Cerec® inlays related to treating dentist

| Treating dentist | No. of inlays ( <i>n</i> ) | Median age (months) | Mean age (months) | Age range (months) |
|------------------|----------------------------|---------------------|-------------------|--------------------|
| A                | 28                         | 15.5                | 15.7              | 12–23              |
| B                | 16                         | 12.5                | 14.0              | 12–18              |
| C                | 14                         | 13.0                | 16.0              | 12–24              |
| D                | 17                         | 13.0                | 13.2              | 12–14              |
| E                | 11                         | 12.0                | 12.0              | 12                 |
| F                | 5                          | 13.0                | 13.4              | 13–14              |
| G                | 88                         | 17.0                | 16.6              | 12–24              |
| H                | 26                         | 19.5                | 18.2              | 12–24              |
| Total            | 205                        | 16.0                | 15.8              | 12–24              |

Table 2. The number of Cerec inlays related to surfaces restored

| Type                 | n   |
|----------------------|-----|
| Class I              | 7   |
| Class II             |     |
| Two-surface inlays   | 74  |
| Three-surface inlays | 95  |
| Four-surface inlays  | 24  |
| Onlays               | 5   |
| Total                | 205 |

Table 3. Distribution of restorations on available homologous teeth

| Type of restoration   | No. of proximal surfaces restored |
|-----------------------|-----------------------------------|
| Isosit inlay/onlay    | 2                                 |
| Gold                  | 8                                 |
| Composite             | 11                                |
| Metal ceramic         | 22                                |
| Amalgam               | 72                                |
| Cerec                 | 147                               |
| Total                 | 262                               |
| Not restored surfaces | 140                               |

The status of the oral mucosa, the temporomandibular joint (TMJ), and the masticatory muscles; the margin index (8); and plaque and bleeding index in accordance with Lenox & Kopczyk (9) were all monitored. For comparison, the periodontal variables were recorded on both Cerec-restored and available homologous surfaces not treated with Cerec inlays (Table 3). The restorative status of the homologous teeth was also recorded.

The Cerec restorations were examined in accordance with the California Dental Association's (CDA) quality evaluation systems (10). After careful calibration the three evaluators, working in pairs, examined all the restorations independently of each other with regard to the CDA criteria. Whenever there was disagreement in the rating of a given restoration, the pair of examiners resolved their disagreement by joint examination. The CDA criteria focus on 'Surface and Color', 'Anatomic Form', and 'Marginal Integrity', and every restoration is given a

rating representing one of the four ranges: 1) range of excellence, 2) range of acceptability, 3) replace or correct for prevention, and 4) replace immediately. Restorations within the ranges of 1 and 2 are considered 'satisfactory', and restorations rated within ranges 3 and 4 are not acceptable.

### Results

The number, median age, and range of the Cerec inlays related to treating dentist are shown in Table 1. One hundred and fifteen inlays were placed in the molar region and 90 in the premolar region. Twenty-three inlays were indirectly designed and manufactured; 52% of these were produced by the same dentist (D in Table 1). The number of inlays related to surfaces restored is shown in Table 2, and the number and type of restorations on homologous teeth are presented in Table 3. On being questioned about why they had been treated with Cerec inlay therapy, 20

Table 4a. Relative number and percentage of restored proximal surfaces with plaque

| Surface | Cerec surfaces (n = 115) |      | Homologous surfaces (n = 115) |      |
|---------|--------------------------|------|-------------------------------|------|
|         | Relative no.             | %    | Relative no.                  | %    |
| Mesial  | 39/55                    | 70.9 | 42/55                         | 76.4 |
| Distal  | 43/60                    | 71.6 | 40/60                         | 66.6 |
| Total   | 82/115                   | 71.3 | 82/115                        | 71.3 |

Table 4b. Relative number and percentage of restored proximal Cerec surfaces versus intact homologous proximal surfaces with plaque

| Surface | Cerec surfaces (n = 61) |      | Homologous surfaces (n = 61) |      |
|---------|-------------------------|------|------------------------------|------|
|         | Relative no.            | %    | Relative no.                 | %    |
| Mesial  | 25/33                   | 75.8 | 26/33                        | 78.9 |
| Distal  | 20/28                   | 71.4 | 18/28                        | 64.3 |
| Total   | 45/61                   | 75.6 | 44/61                        | 72.1 |

patients reported aversion to metallic restorative materials in general and dental amalgam in particular. Forty-one patients reported that they had been advised to choose Cerec therapy by their dentist, and 11 patients reported that esthetic reasons lay behind the replacement with Cerec inlays.

Ten patients reported postoperative sensitivity after inlay placements, a situation that still remained in one case at the time of examination. In another case the postoperative sensitivity resulted in endodontic treatment. In addition, two patients reported a permanent loss of occlusal fidelity.

The clinical examination showed that eight patients had signs of lichenoid lesion of the buccal mucosa, none of them with any topographic relationship to the restorations examined. Seven patients had clicking sensations from the TMJ, whereas three patients had tenderness on palpation from the masticatory muscles. Neither proximal plaque nor bleeding on probing was seen more often in relation to Cerec inlay surfaces than to homologous control surfaces (Tables 4 and 5). Several of the 140 intact proximal surfaces on homologous teeth (Table 3) did not have a corresponding Cerec-restored proximal surface on their homologous teeth—that is, an MO or DO Cerec inlay had been made. This means that there were totally 61 proximal surfaces with Cerec restorations to compare with intact homologous proximal surfaces (Tables 4b and 5b).

With regard to the margin index of the Cerec inlays, most of them had margins that were placed subgingivally (score 3, Table 6).

In the examinations using the criteria of the CDA, excellent ratings for Color were obtained for 57% of the inlays. The corresponding excellent ratings were for Surface, 26%; for Anatomic Form, 55%; and for Margin Integrity, 83%. The number and percentages of inlays that did not receive an excellent CDA rating are presented in Table 7.

A slight color mismatch (SMM) between the inlay and the tooth structure was seen in 43% of the inlays. Slightly roughened surfaces (SRO) were quite often seen with the Cerec inlays. Common findings with regard to Anatomic Form were slightly undercontoured marginal ridges (SMR) and slightly overcontoured axial surfaces (SOCO). With regard to Margin Integrity, visible evidence of ditching (SCR) along the inlay margin was seen in 13% of the Cerec inlays. The four inlays with fractured surfaces (VFR) were still functioning. Only minor parts of marginal ridges had fractured, and the inlays were adjusted by grinding and polishing.

The relationship between quality ratings of the different dentists is presented in Table 8. The overall best results were produced by dentist B, and the greatest differences between the dentists were seen for the ratings of Color and Anatomic Form. No systematic difference was observed between the vast majority of Cerec inlays directly produced and those indirectly produced—that is, from a replica of the tooth cavity.

The initial interexaminer agreement was 89% for one pair of examiners and 97% for the other pair.

Table 5a. Relative number and percentage of restored proximal surfaces with bleeding

| Surface | Cerec surfaces<br>(n = 115) |      | Homologous<br>surfaces (n = 115) |      |
|---------|-----------------------------|------|----------------------------------|------|
|         | Relative no.                | %    | Relative no.                     | %    |
| Mesial  | 25/55                       | 45.5 | 21/55                            | 38.2 |
| Distal  | 18/60                       | 30.0 | 20/60                            | 33.3 |
| Total   | 43/115                      | 37.4 | 41/115                           | 35.7 |

Table 5b. Relative number and percentage of restored proximal Cerec surfaces versus intact homologous proximal surfaces with bleeding

| Surface | Cerec surfaces<br>(n = 61) |      | Homologous<br>surfaces (n = 61) |      |
|---------|----------------------------|------|---------------------------------|------|
|         | Relative no.               | %    | Relative no.                    | %    |
| Mesial  | 19/33                      | 57.6 | 18/33                           | 54.5 |
| Distal  | 10/28                      | 35.7 | 8/28                            | 28.6 |
| Total   | 29/61                      | 47.5 | 26/61                           | 42.6 |

Table 6. Margin index scores\* of Cerec proximal surfaces

| Surface                  | Score 0 | Score 1 | Score 2 | Score 3 |
|--------------------------|---------|---------|---------|---------|
| Mesial ( <i>n</i> = 142) | 6       | 17      | 28      | 91      |
| Distal ( <i>n</i> = 160) | 6       | 12      | 34      | 108     |

\* Score 0 = restoration margin > 2 mm above the gingival margin; score 1 = < 2 mm above the margin; score 2 = at the gingival margin; score 3 = below the gingival margin.

Table 7. Percentages and number of Cerec inlays (*n* = 205) that did not receive an excellent CDA rating\*

|          | Surface and Color |      | Anatomic Form |      |      |     | Margin Integrity |      |     |     |
|----------|-------------------|------|---------------|------|------|-----|------------------|------|-----|-----|
|          | SRO               | SMM  | SMR           | SUCO | SOCO | TCO | SCR              | SDIS | TMD | VFR |
| %        | 73.7              | 43.4 | 24.4          | 2.9  | 17.1 | 0.5 | 13.2             | 1.5  | 0.5 | 2.0 |
| <i>n</i> | 151               | 89   | 50            | 6    | 35   | 1   | 27               | 3    | 1   | 4   |

\* SRO = surface of restoration is slightly rough or pitted, can be polished; SMM = slight mismatch between restoration and tooth structure within the normal range of tooth color, shade, and/or translucency; SMR = marginal ridges slightly undercontoured; SUCO = restoration is slightly undercontoured; SOCO = restoration is slightly overcontoured; TCO = contact is faulty (self-correction is unlikely); SCR = visible evidence of ditching along the margin not extending to the DE junction; SDIS = discoloration on the margin between the restoration and the tooth structure; TMD = dentin is exposed; VFR = restoration is fractured.

## Discussion

More than half of the patients who took part in the present study reported that the reason for having a Cerec inlay done was that they had been advised by their dentist to choose this therapy. The rest had this type of ceramic inlay for esthetic reasons (15%) or because they wanted to avoid any metallic restoration (28%). Considering the fact that about 56% of the restorations were done in the molar region, it is understandable that esthetics was not the main reason for the patients to choose Cerec inlays. However, since there is a fairly widespread fear of side effects from dental metallic restorative materials, especially related to amalgam, among the general public, it is not surprising that 28% of the patients preferred to have a nonmetallic restoration. When a ceramic inlay was the therapy of choice, it is reasonable that a Cerec inlay was often suggested

by the treating dentist who had learned this technique and had access to Cerec equipment.

Ten (14%) of the 72 patients with Cerec inlays reported postoperative sensitivity, a symptom that in one case necessitated endodontic treatment. It has previously been reported (11, 12) that from 16% and up to 30% of teeth restored with tooth-colored—that is, composite and ceramic—inlays had postoperative sensitivity, occurring mainly on loading. This effect has been ascribed to factors such as trauma during cavity preparation, unintentional etching of dentin, desiccation of dentin, toxicity of composite components, polymerization contraction of the composite with concomitant marginal leakage, and bacterial invasion of the gap (13, 14). Occlusal load in addition to microleakage with transmission of a hydraulic pressure to the odontoblastic layer or pulpal nerve will further influence the process (15).

Table 8. Percentage distribution of Cerec inlays ( $n = 205$ ) that did not receive an excellent CDA rating\* with regard to treating dentist

| Dentist | <i>n</i> | Surface and Color |      | Anatomic Form |      |      | Margin Integrity |      |      |     |     |
|---------|----------|-------------------|------|---------------|------|------|------------------|------|------|-----|-----|
|         |          | SRO               | SMM  | SMR           | SUCO | SOCO | TCO              | SCR  | SDIS | TMD | VFR |
| A       | 28       | 100               | 14.3 | 32.1          | 7.1  | 14.3 | 3.6              | 10.7 |      |     |     |
| B       | 16       |                   |      |               |      | 6.3  |                  |      |      |     |     |
| C       | 14       | 57.1              | 42.9 |               | 14.3 | 42.9 |                  |      |      |     |     |
| D       | 17       | 100               | 35.3 | 5.9           | 5.9  | 23.5 |                  | 5.5  |      |     |     |
| E       | 11       | 100               | 54.5 | 18.2          | 9.1  | 45.5 |                  | 36.4 |      |     | 9.1 |
| F       | 5        | 60.0              | 80.0 |               |      | 40.0 |                  | 20.0 |      |     |     |
| G       | 88       | 65.9              | 51.1 | 30.7          |      | 14.8 |                  | 6.8  | 3.4  | 1.1 | 3.4 |
| H       | 26       | 100               | 69.2 | 42.3          |      |      |                  | 46.2 | 3.8  |     |     |

\* The abbreviations of the ratings are explained in Table 7.

In the present study no systematic observation could explain the frequency of post-operative sensitivity, which means that probably several of the above-mentioned factors were involved. It is important that factors such as those proposed or presented in the current literature (13–16) are studied further with special reference to the adhesive cementation technique.

Anamnestic information showed that two patients were bothered by permanent loss of occlusal fidelity after having their Cerec inlays placed. This side effect of the treatment strongly emphasizes the importance of careful occlusal adjustment of a Cerec inlay, the occlusal surface of which is only roughly shaped by the CNC milling device. The occlusal adjustment is often the most time-consuming part of the production of a Cerec inlay, but it has to be carried out in a proper manner to prevent clinical problems.

Seven other patients had clicking sensations from the TMJ, and three had tenderness of the masticatory muscles on palpation, but there were no reasons to relate these symptoms to the presence of Cerec inlays. Nor was any such relationship found among the eight patients with lichenoid lesions of the buccal mucosa, since these lesions were not topographically related to the Cerec inlays.

In the present study most of the inlays had margins that were placed subgingivally (Table 6). Considering this fact, the Margin

Integrity rating using the CDA criteria was satisfactory, with 83% excellent margins. In a clinical study evaluating 37 cast Dicor (Dentsply Int, Wiesbaden, Germany) inlays, in situ for 1–22 months, Bessing & Molin rated 68% of the inlays as having excellent Margin Integrity (16). In the latter study most of the inlays that did not receive an excellent rating for Margin Integrity had been placed using zinc phosphate or glass polyalkenoate cement, whereas Cavel et al. (17) in an in vivo pilot study of 31 cast Dicor inlays luted with a dual-cure resin cement found 100% excellent margins after 6 months in situ. In the present study all the 205 inlays had been luted with dual-cure resin cement. However, the inlays had been made by eight different dentists, and the observation time was longer, 12–24 months, and it is therefore reasonable to assume that 100% excellent ratings for Marginal Integrity could not be attained.

With regard to Color only 57% of the inlays received excellent ratings. This probably reflects the restricted selection of colors available among the prefabricated blocks. Considering that all the restorations were made in premolars and molars, the slight color mismatch (SMM) between inlay and tooth structure that was registered in 43% of the inlays is probably of little importance.

However, the low percentages of excellent ratings for Surface (26%) and Anatomic Form (55%) are obvious. With regard to

Anatomic Form this can be ascribed to insufficient care in shaping the outside of the inlay. As has already been pointed out, this is a most time-consuming process that is often difficult to carry out with appropriate accuracy directly in the mouth. With regard to the Surface ratings, slightly roughened surfaces (SRO) were quite commonly (74%) seen with the Cerec inlays. The Vita Mk I blocks, which should be the ones used for most of the inlays in the present study, are said to have a coarser structure than the Vita Mk II and Dicor blocks, which were introduced on the market at a later date. Nevertheless, Vita Mk I can also be highly polished, but if there are too many polishing steps, a clinically unrealistic amount of time will be needed. In addition, it is important to be aware that all polishing procedures will cause some wear on the marginal cement. It might therefore be expected that the improved ceramics of finer structure which may be used today for the manufacturing of Cerec blocks will make it possible to attain a smoother surface for the inlays. This is at present being studied separately.

Among the homologous teeth, which were not restored with Cerec inlays, 140 proximal surfaces were not restored at all, and 115 proximal surfaces had common types of restorative materials (Table 3). As can be seen in Tables 4 and 5, proximal plaque and bleeding on probing were not more frequently related to the presence of Cerec inlays than to homologous control surfaces, both intact and restored. However, a roughened surface may in the long run facilitate the accumulation of plaque and may also cause an unfavorable wear of opposing teeth. It is therefore important that the manufacturers furnish dentistry with ceramic blocks that can be highly polished in a clinically realistic manner.

The reason why there were not more plaque and bleeding related to Cerec inlays than to the homologous control surfaces might be that the proximal Cerec surfaces were smooth and well polished because, in contrast to the occlusal surface, they are always polished outside the mouth before cementation.

The most important difference observed

among the participating dentists with regard to the quality of the Cerec inlays was related to the CDA variable Anatomic Form. This indicates that successful work with the Cerec technique requires not only a trained dentist but also a dentist who allows him- or herself enough time for occlusal adjustment and grinding-in procedures.

### Conclusion

Considering the results of the present study, even though it covers only a limited time of 12–24 months, it seems reasonable to assume that the Cerec system may function well in the hands of a skilled dentist. The main problem observed was the high frequency of rough surfaces on the Cerec restorations. It is therefore important that the block material per se has a satisfactorily fine structure. Furthermore, it must be required that a manufacturer of ceramic blocks for machining provides well-founded and clinically realistic step-by-step recommendations for the polishing of the inlays.

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