Clinical and Experimental Study of Ceramic Inlays versus Composite Inlays

Gerwin Arnetzl, Klaus König, Karl W. Wintersteller, Martin Lorenzoni

Acid etching and filled acrylic materials have been generating great interest in the past few years because of increased public demand for esthetic restorations and alternatives to amalgam. Composite resin and ceramic inlays, which use adhesive bonding, were introduced to make possible tooth-colored restorations.

The physical properties of composite resin restorations, and their poor wear resistance, have been known for a considerable time.1, 2 While heat-treated composite resin inlays exhibit significantly better homogeneity and marginal adaptation than conventional intraorally cured inlays, poor abrasion resistance and rapid degradation of the marginal integrity raised doubts as to their suitability for occlusal restorations. According to Marolf, composite resin inlays have a service life of 3 to 5 years.

Whether composite inlays are suitable for occlusal restorations is still a controversial subject, especially since no longitudinal studies have been carried out to date.3-7 That exact primary marginal fit is possible was proved in numerous experimental and clinical studies.8-10 However, even improved systems cannot prevent disintegration at the inlay-bonding composite interface after subjection to thermal and mechanical stresses or several months of intraoral service.2, 5, 11

The physical properties of porcelain and ceramic are comparable to those of dentin. The material is chemically inert; thermal expansion is similar to that of the tooth.12 Horn13 and Calamia and Simonsen14, 15 conclude that porcelain etching enhances retention and thus produces a clinically stable and durable blood with the dentin.

While castable ceramic and composite inlays (indirect fabrication) are produced from an impression and cast, the Cerec® system permits the direct fabrication of a restoration during a single dental appointment. The cavity is scanned by stereophotogrammetry and the restoration machined from ceramic blocks.

Moermann,11 in a series of laboratory experiments in which he subjected restorations to 2,500 temperature cycles, was able to prove that Cerec inlays showed significantly improved marginal adaptation compared to amalgam and gold.

In another study, comparing Cerec inlays and onlays with porcelain, glass ceramic, and experimental composite blocks, "perfect margins" of 98% to 100% were reported, provided the preparation margins were situated in enamel. For approximal margins placed in dentin, much lower "perfect margin" percentages (46% to 61%) were recorded.16

This article reports on a clinical and experimental study carried out to compare different indirect ceramic and composite resin inlay systems.

Materials and Methods

In the experimental part of this study human teeth were extracted, randomly divided into groups of six specimens each, and restored employing the different restoration systems. A total of 60 teeth were then checked for marginal adaptation and leakage using a dark-field direct-light microscope and color penetration testing. In each group 24 sites of measurement were evaluated (12 occlusal and 12 approximal).

The analyses were conducted after the teeth had been thermocycled 2,000 times at temperatures...
For the control group, bevels of 50 to 70 degrees on approximal surfaces of box forms were prepared. Heavy chamfers of approximately 150 to 160 degrees were made on occlusal surfaces. For the composite, ceramic, and porcelain inlays, preparation without rounded internal angles or beveled margins was employed. All the preparation margins placed in dentin were smoothed using finishing diamonds, Arkansas stones, or hand-held instruments, depending on the accessibility of the site. Two hydrocolloid impressions were made of each prepared tooth. A cast was poured from each impression using Fuji-Rock special plaster cast. The Optec and Coltène composite inlays were fabricated in the laboratories of the various manufacturers. The Degulor-C, Kulzer, and Isosit composite inlays were fabricated in our own laboratory. The inlays were fitted on the casts and pretreated prior to bonding. Depending on the inlay system used, the following materials were employed: Dicor and Biodent Retention gel; Du-Ceram and Biodent Retention gel or Stripit; Optec and Stripit, and Cerec and Cerec Etch.

The internal surfaces of the ceramic and porcelain inlays were etched for 1 minute, then rinsed for 1 minute, and thoroughly dried before a cold silane conditioner (Silicoup) was applied. (Bonding was effected after acid etching in the usual manner employing a coffer dam.) For the control group, zinc phosphate cement was used for the cementation of the restoration (Mizzy-Fleck's cement). To finish the margins, sand paper disks (Moore) were utilized while the cement was setting, and for the approximal surfaces, diamond tips in an EVA handpiece (Proxoshape) were used. The following materials were used (according to manufacturer's information): Degulor, Coltène composite, Kulzer composite, SR-Ilosit, Optec, Hi-Ceram, Du-Ceram, Dicor, Cerec, Mizzy-Fleck's cement, Duo cement, Microfill Pontic, Dual cement, Tulux cement, Microfill Pontic, Tulux cement, Tulux cement, and Duo cement.

The restorations were finished and polished using diamonds and flexible disks. The approximal margins were abraded using the EVA system and Proxoshape files with decreasing diamond grain sizes and finally polished. When dual-curing Tulux
cement is employed, excess material can be easily removed after the first polymerization phase while it is still plastic and can be trimmed with a scalpel. After the second polymerization phase the same instruments as described above can be employed to finish and polish the restoration. The teeth were placed in 5% erythrosin solution (pH = 7) at 40°C for 2 hours. After being embedded in Technovit, the teeth were cut mesiodistally and buccolingually with an Isomet diamond saw. Color penetration was checked under the dark-field direct-light microscope, rated Yes or No, and recorded as percentage. Occlusal and approximal sites were evaluated separately. Marginal gaps were measured by dark-field direct-light microscope examination (magnification × 100) at 24 sites per group. The magnifying power of the microscope allows an accuracy of ± 5 µm. Random sampling was employed. Major variations in marginal adaptation in a single sample were observed. Because measurements were taken at a large number of sites (n = 24) these inaccuracies can be neglected in the statistical analysis. From the 68 patients who participated in the clinical study, 210 teeth were tested at six-month intervals for excessive wear; fractures of the tooth or restoration; degradation of the restoration margin (substantial loss of enamel, bonding composite, or restoration); caries; and pulпитis (vitality). The results were considered positive if no such changes were found. Differences in the availability of the various systems resulted in different observation periods (Fig 2). For the statistical comparison 30 teeth were selected at random for each inlay and evaluated intraorally at recall visits after 2, 3, and 5 years.

Results

The results of the color penetration tests and clinical examinations were checked for frequency differences employing the chi-square test with a maximal 10% error of probability. Figure 3 shows the percentage of specimens with perfect margins (no color penetration) after thermocycling and mechanical stress. No statistically significant differences between occlusal and approximal sites were observed in any of the groups. The

<table>
<thead>
<tr>
<th></th>
<th>occlusal</th>
<th>proximal</th>
<th>total</th>
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<tbody>
<tr>
<td>Degulor C</td>
<td>70%</td>
<td>75%</td>
<td>72%</td>
</tr>
<tr>
<td>Dicor</td>
<td>80%</td>
<td>78%</td>
<td>80%</td>
</tr>
<tr>
<td>Optec</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Cerec</td>
<td>77%</td>
<td>82%</td>
<td>80%</td>
</tr>
<tr>
<td>Du-Ceram</td>
<td>76%</td>
<td>78%</td>
<td>76%</td>
</tr>
<tr>
<td>Kulzer composite</td>
<td>70%</td>
<td>75%</td>
<td>72%</td>
</tr>
<tr>
<td>Coltène composite</td>
<td>78%</td>
<td>76%</td>
<td>76%</td>
</tr>
<tr>
<td>SR-Isosit composite</td>
<td>77%</td>
<td>75%</td>
<td>75%</td>
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</table>

Fig 3 Perfect margins (in %) without color penetration after thermocycling and mechanical stress.
The Kruskal-Wallis test records statistically highly significant variations for all groups ($P < .001$). The results of the Wilcoxon test as regards marginal fit were as follows.

1. Highly significant differences ($P < .001$) were found between Cerec inlays and gold, Kulzer, and Coltène composite inlays.

2. A significant difference ($P < .01$) was found between Cerec inlays and SR Isosit.
3. Significantly better results for sinter ceramic Optec and Du-Ceram inlays as compared to Dicor inlays.

4. Probably significant difference ($P < .05$) was noted between sinter ceramics Optec and Du-Ceram and Cerec inlays.

5. Probably significantly poorer results were obtained for sinter ceramics as compared to composite inlays.

6. No differences between the different composite systems.

7. No differences in marginal fit between Optec and Du-Ceram inlays.

8. No differences between the Dicor and Cerec systems.

9. No differences between gold inlays and Optec and composite inlays.

Table 1  Clinical results, 2 years: inlays with no negative ratings ($n = 30$)

<table>
<thead>
<tr>
<th>Inlay</th>
<th>% no negative ratings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degulor C: control group</td>
<td>100</td>
</tr>
<tr>
<td>Dicor</td>
<td>100</td>
</tr>
<tr>
<td>Optec</td>
<td>100</td>
</tr>
<tr>
<td>Cerec</td>
<td>87</td>
</tr>
<tr>
<td>Du-Ceram</td>
<td>100</td>
</tr>
<tr>
<td>Kulzer composite</td>
<td>80 $P &lt; .05$</td>
</tr>
<tr>
<td>Coltène composite</td>
<td>80 $P &lt; .05$</td>
</tr>
</tbody>
</table>

* Chi-Square test: $P < .05$. A probably significant difference exists between the 100% groups and the composite inlays.

Table 2  Clinical results, 3 years: inlays with no negative ratings ($n = 30$)

<table>
<thead>
<tr>
<th>Inlay</th>
<th>% no negative ratings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degulor C: control group</td>
<td>100</td>
</tr>
<tr>
<td>Dicor</td>
<td>93</td>
</tr>
<tr>
<td>Optec</td>
<td>80 $P &lt; .05$</td>
</tr>
<tr>
<td>Cerec</td>
<td>87</td>
</tr>
<tr>
<td>Du-Ceram</td>
<td>90</td>
</tr>
<tr>
<td>Coltène composite</td>
<td>80 $P &lt; .05$</td>
</tr>
</tbody>
</table>

* Chi-Square test: $P < .05$. Probably significant differences were observed between the gold inlay and the Optec, Hi-Ceram, and Coltène systems.
**Clinical Examination**

2,3 and 5 Years Results

<table>
<thead>
<tr>
<th>Inlays Without Negative Consideration in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Years</td>
</tr>
<tr>
<td>Degulo C</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

**Figure 7** Inlays without negative clinical consideration.

Table 3 Clinical results, 5 years: inlays with no negative ratings (n = 30)

<table>
<thead>
<tr>
<th>Inlay</th>
<th>% No Negative Ratings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degulo C: control</td>
<td>100</td>
</tr>
<tr>
<td>Dicor</td>
<td>93</td>
</tr>
<tr>
<td>Coltene composite</td>
<td>80 <em>P &lt; .05</em></td>
</tr>
</tbody>
</table>

*Chi-Square test: *P* < .05. After 5 years, probably significant differences were observed between the gold inlay and the Coltene composite inlay systems.

In two cases (Optec) fractures occurred within 8 months after placement of the inlays. Secondary caries developed in eight cases (three Optec, two Cerec, three composite) after 13 to 24 months. No complications developed with the gold inlays. Periodontal or endodontic problems did not develop in any of the groups. In 28 (24.09%) of the 210 teeth evaluated, postoperative sensitivity was reported immediately after bonding. In all such instances, however, this problem disappeared within 2 months (Fig 7).

**Discussion**

Mechanical stress and differences in thermal expansion between tooth and restoration are the main reasons for loss of marginal adaptation, even in cases of exact primary marginal fit. The marginal gaps recorded in this study are comparable to those found by other investigators. 

Better marginal fit was obtained with sinter ceramics, where margins are easy to correct, than with glass ceramics. Whether beveling improves retention to the enamel is still as controversial today as the recommended limits for the cementing margins. 

With adhesive bonding the question of marginal fit is raised again. Although gold and Cerec inlays form very different marginal gaps, the two systems produce comparable results in color penetration tests. It has been reported that better marginal integrity of ceramic inlays is achieved with wide rather than with narrow marginal gaps. It has also been found that poor primary fit in laboratory-fabricated ceramic and Cerec inlays is compensated for by a
favorable coefficient of thermal expansion. Yet, systems that permit exact fit should be given preference, because undercuts and porosities due to “cementation deficiencies” are easier to avoid in clinical application.

Brief reference is made again here to the application of specific, material-dependent, etching agents prior to cementation. Current scientific knowledge gives no clear answer to whether silane conditioner should be applied.16, 24

The results obtained in the experiments alone permit no conclusions as to which of the tested systems should be preferred, because additional parameters, such as occlusion, plaque aggression, abrasion resistance, or such specific clinical difficulties as removal of excess material during preparation are not taken into account. Our examinations during recall visits showed that even after 5 years, acceptable results were obtained for ceramic and composite inlays, yet in comparison to gold inlays, they tend to exhibit rapid disintegration of the margins.

The hypersensitivity rate of 14% corresponds with that found by Hickel.25 Hickel suggested that hypersensitivity could be caused by etching of exposed dentin, polymerization shrinkage of the bonding agent, development of a contraction gap, and expansion of the acrylic resin inlay because of water absorption. In addition, the rigid bond between tooth and restoration could be a factor.

The conventional concept of retention has to be redefined for ceramics inlays.5 Adhesive bonding permits the non-destructive restoration of teeth and protects them from fracture, even if the teeth are pulpless. The enormous expense of this bonding technique, however, rules out the possibility of using these inlays as alternatives to amalgam restorations. Long-term (10- to 15-year) clinical studies will have to prove that tooth-colored inlays are an adequate substitute for gold.

Materials

- Biodent retention gel
- Cerec Etch
- Cerec-System
- Coltène composite inlay
- Degulor C
- Dicor
- Dual-Cement
- Du-Ceram
- EVA handpiece
- Fuji-Rock
- Isomet diamond saw
- Kulzer composite inlay
- Microfill-Pontic
- Mizzy-Fleck's Zement
- Moore disks
- Proxoshape
- Silicoup
- Soflex Disk
- Stripit
- T&F Hybrid Points kit
- Technovit
- Optec

Dentsply, Dreieich, FRG
Vita, Bad Säckingen, FRG
Brains, CH-8702 Zollikon
Coltène, CH-9450 Altstätten
Ögussa, A-1090 Vienna
DeTrey GesmbH, D-62000 Wiesbaden
Vivadent, FL-9494 Schaan
Ducera Dental GmbH, D-63650 Rosbach
KaVo, Bieberach/Fiss, FRG
GC Dental Ind. Corp., Tokyo, Japan
Ivoclar AG, FL-9494 Schaan
Kulzer & Co GesmbH, Werheim/Ts, FRG
Kulzer & Co GesmbH, Werheim/Ts, FRG
Mizzy Inc., Clifton Farge, VA, USA
Moore Comp., Inc., Dearborn, USA
Intensiv SA, CH-6962 Vaganello-Lugano
Kulzer & Co GesmbH, Werheim/Ts, FRG
3M & Co, Minnesota, USA
Renfert, Singen, FRG
Shofu Inc., Japan
Kulzer & Co GesmbH, Werheim/Ts, FRG
Jeneric-Pentron, Wallingford, CT 06492, USA
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