Interface gap size of manually and CAD/CAM-manufactured ceramic inlays/onlays in vitro

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Received 27 November 2000; revised 27 July 2001; accepted 5 October 2001

Abstract

Objectives: To determine the fit of ceramic inlays manufactured using a recently introduced CAD/CAM-system (Decim) and of two types of laboratory-made heat-pressed ceramics (IPS Empress and Opc).

Materials and methods: Extracted human premolars were prepared to receive mesio-occlusodistal (MOD) ceramic inlays, for which 10 Denzir, 10 IPS Empress, and 10 Opc were fabricated. The Denzir restorations were produced by the manufacturer of the CAD/CAM-system, and the IPS Empress and Opc by student dental technicians. Before luting the internal fit on the diestone models and on the premolars was determined using replicas. After luting on the premolars with a resin composite the marginal and internal fit were measured. The values were analyzed statistically using ANOVA and Scheffe’s test at a significance level of \( p < 0.05 \).

Results: Before luting there were no significant differences \( (p > 0.05) \) in the internal gap width between the three systems studied when placed on their matching diestone models. When placed on the premolars a significant difference \( (p < 0.01) \) in the internal fit was seen between Empress and Opc before luting, whereas there were no significant differences \( (p > 0.05) \) between Empress and Denzir and between Opc and Denzir. Between the diestone models and the premolars there were significant differences \( (p < 0.01) \) in the internal fit, except for IPS Empress. After luting there were no significant differences \( (p > 0.05) \) between IPS Empress and Denzir, whereas the marginal gap width was significantly wider \( (p < 0.001) \) for Opc than for IPS Empress and Denzir. The internal fit was significantly \( (p < 0.001) \) wider for Opc than for IPS Empress, whereas there were no significant differences \( (p > 0.05) \) between IPS Empress and Denzir or between Opc and Denzir.

Conclusion: After luting there were only slight differences in the fit between the restorations fabricated using the three different manufacturing techniques and ceramics. Therefore, long-term follow-up studies are needed to assess the clinical significance of the slight differences between the three systems. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Ceramic, Ceramic inlays; Composite; Dental materials; Marginal gap; Internal gap; Inlays

1. Introduction

The increased use of ceramic inlays luted with resin composite cements and the introduction of CAD/CAM as a manufacturing technique have intensified the debate about the internal and marginal fit of dental restorations [1–10]. The influence of the luting agent properties on the final marginal and internal gap widths has also been the subject of debate [8–10]. Recently another CAD/CAM-system for manufacturing dental restorations, the Decim system, has been introduced onto the market [11]. This system utilizes prefabricated yttrium-oxide-partially-stabilized zirconia ceramic blocks for manufacturing ceramic inlays, marketed as Denzir [11]. For ceramic inlays manually manufactured in dental laboratories a commonly used technique is heat-pressing [12,13]. Examples of inlays manufactured using this technique are the heat-pressed IPS Empress, introduced in 1990, and the heat-pressed Optimal Pressable Ceramics (Opc), introduced in 1996. Those heat-press systems utilize the lost-wax technique and both systems utilize leucite-reinforced ceramics and the manufacturing technique and materials are broadly considered to be equal. The inlay systems mentioned thus represent two different manufacturing techniques, i.e. the commonly used press casting [12,13] and the CAD/CAM-techniques [14]. It was therefore of interest to study whether the different manufacturing processes and ceramics influence the fit of the restorations. Thus, the aim of the present study was to determine the internal and marginal fit of ceramic inlays fabricated using these two different manufacturing techniques and three ceramics.

2. Materials and methods

Thirty sound, caries-free, extracted human mandibular
premolars were prepared for mesio-occlusodistal (MOD) ceramic inlays. The extracted premolars had been stored in 0.5% benzalconium chloride solution. The preparation design of the cavities for the ceramic inlays was based on the concept of standard class-II preparations with a flat bottom and all angles rounded. All the cavities were prepared with cervical shoulders with no cavosurface bevels. The preparation depth was about 2 mm and the walls of the preparations were prepared to meet the tooth surface at or near a right angle. All the cavity margins were located in enamel. The width in the bucco-lingual direction was half that of the inter-cuspal dimension. The prepared premolars were then randomly divided into three groups of 10, for which 10 IPS Empress (Ivoclair AG, Schaan, Lichtenstein), 10 Optimal Pressable Ceramics (Opc, Jeneric Pentron, Wellington, CT, USA), or 10 Denzir (Decim AB, Skellettea, Sweden) ceramic inlays were intended. For the 10 premolars intended for the Denzir inlays, the preparation of the cavity was thereafter adjusted in accordance with the manufacturer’s information, i.e. the convergence angle was made wider, all internal angles rounded with a diameter of at least 1.5 mm, and the height of the lingual cusp cut = 1 mm. The same person performed all tooth preparation. After impression with an A-silicon (Provil Light and Heavy Body, Bayer Dental, Leverkusen, Germany. Batch number of the catalyst 080136 and of the base 080116 for the light body and 020636 of the catalyst and 020625 of the base for the heavy body) diestone models (Kerr Vel-Mix Stone ISO Type IV; Kerr Europe AG, Basel, Switzerland) of the prepared teeth were manufactured. Thereafter 10 IPS Empress inlays, fabricated using a lost-wax casting technique, 10 Opc inlays, fabricated using a lost-wax casting technique, and 10 Denzir onlays, fabricated using a CAD/CAM-technique, were manufactured. A student dental technician produced all IPS Empress and Opc inlays during his final two months before graduation from the Dental Technician School, Umeå University, Umeå, Sweden, with the exception of 1 Opc inlay made by another student dental technician, because one Opc inlay was accidentally lost. The student dental technicians worked under supervision of an experienced certified dental technician. Decim AB fabricated the Denzir onlays after the diestone models and the A-silicon impressions intended for the Denzir onlays were sent to Decim AB. All 30 restorations were produced strictly in accordance with the manufacturers’ instructions and were judged by an experienced dentist to be acceptable for permanent placing in patients.

To determine the internal fit of the restorations before luting, the cavities of the prepared teeth were filled with an A-silicon (Provil Light Body, batch number of the catalyst 080136 and of the base 080116) and the matching restoration was placed with firm finger pressure in the cavity. After the light body impression material had polymerized the restorations were removed and the cavity was filled with Provil Heavy Body (batchnumber of the catalyst 020636 and of the base 020625) that differed in color from the Provil Light Body. After polymerization the impressions were removed from the cavity and divided with a scalpel in the mesio-distal direction at or near the center [15]. The internal gap width was then measured with a Leitz UWM-DigS measuring microscope at seven preselected locations (Fig. 1) at 10× magnification. The gap width was measured as the thickness of the Provil Light Body impression material at the measuring points. The internal fit of the restorations placed on the matching diestone models was also determined using the same technique and materials as described above.

Subsequently the internal surfaces of the Opc and IPS Empress inlays were pretreated with HF-acid for 1 min and with silane for 1 min; the internal surfaces of the Denzir onlays were treated with 37% phosphoric acid gel for 1 min in accordance with the manufacturers’ instructions. The restorations were subsequently luted on the matching teeth with a dual-cured resin composite cement (Panavia F, Kurary, Osaka, Japan, batch number 00312A). Before luting, the enamel margins and the dentin of the prepared teeth were etched with a 37% phosphoric acid gel, the teeth rinsed in water and dried with compressed air. The restorations were seated on the prepared teeth at room temperature with firm finger pressure as at clinical cementation. The luting agent was polymerized by means of a halogen lamp (Norlite, Germany) for 60 s. Excess cement was then removed with superfine diamonds and/or Sof-Lex polishing disks (3M Dental Products Division, St Paul, Minn., USA). The restored teeth were then placed in a solution of 4% erythrosine (LIC Dental, Solna, Sweden) and 95 vol% ethyl alcohol in white spirit for 7 days to make the resin composite cement in the margin between the enamel and ceramic restorations clearly visible [8]. The marginal fit was thereafter determined at 13 preselected locations (Fig. 2a–d) using the Leitz UWM-DigS measuring microscope at 10× magnification. The gap width was measured as the shortest distance between the cavosurface margin and the restoration at the measuring points. Subsequently, the teeth with the luted restorations were ground from the lingual
Fig. 2. (a) Location of the mesial and distal measuring points for the IPS Empress and Opc restorations. (b) Location of the mesial and distal measuring points for the Denzir restorations. (c) Location of the occlusal measuring points for the IPS Empress and Opc restorations. (d) Location of the occlusal measuring points for the Denzir restorations.

*For the Denzir specimens, the measuring points O, P, and Q were located at the interface between the restoration and the enamel on the surface of the lingual cusp.

The measured values were analyzed statistically with ANOVA and Scheffe’s test at a significance level of \( p < 0.05 \).

3. Results

3.1. Before luting

The mean values, standard deviations, and ranges determined for the internal fit of the restorations placed on their matching diestone models and on their matching premolars before luting are presented in Table 1. Before luting there were no significant differences \(( p > 0.05 \)) in the internal gap width between the three systems studied when placed on their matching diestone models. When placed on their matching teeth before luting, and compared to when they were placed on their matching diestone models, there were significant differences in the internal gap width, with the exception of the IPS Empress restorations. The internal gap width was significantly wider for the Denzir \(( p < 0.01 \)) and Opc \(( p < 0.001 \)) restorations placed on the matching teeth compared to when they were placed on the matching diestone models before luting. When the restorations were placed on their matching teeth comparison of the internal fit between the three systems studied revealed that the internal gap width for Opc was significantly \(( p < 0.01 \)) wider than for IPS Empress, whereas there were no significant differences \(( p > 0.05 \)) between IPS Empress and Denzir or between Opc and Denzir before luting (Table 1).

3.2. After luting

In Table 2 the mean values, standard deviations, and ranges determined for the marginal and internal fit of the restorations after luting on the premolars are shown.

After luting there were no significant differences \(( p > 0.05 \)) between IPS Empress and Denzir with respect to the occlusal, proximal, gingivo-proximal, and internal fit, whereas the occlusal, proximal, and gingivo-proximal gap width were significantly wider \(( p < 0.001 \)) for Opc than for IPS Empress and Denzir. The internal fit was significantly \(( p < 0.001 \)) wider for Opc than for IPS Empress, whereas there were no significant differences \(( p > 0.05 \)) between IPS Empress and Denzir or between Opc and Denzir with respect to the internal fit after luting (Table 2). When the restorations were placed on the matching premolars before luting, and compared to when they were placed on the matching premolars after luting, there was no significant difference \(( p > 0.05 \)) in the internal gap width.

4. Discussions

Clinical survival of ceramic restorations seems to depend
among others things on the properties of the luting agents used [17]. The marginal and internal gap between the inlay and the tooth substance can influence the longevity of the restoration and wear, discoloration, leakage, dissolution, physic-chemical degradation of the luting agent, and the restorations’ ability to withstand loading can be affected of the marginal and internal gap size [1,2,18,19]. New techniques and ceramic materials have therefore been introduced in an attempt to improve the marginal and internal fit of the restorations. Examples of new manufacturing techniques introduced in dentistry are the CAD/CAM-technique and the commonly used pressable ceramics. The CAD/CAM-technique was introduced into dentistry at the beginning of the eighties and different systems have been presented [14]. The CAD/CAM-system evaluated in the present study has been introduced recently and is marketed as Decim [11]. The Decim system utilizes prefabricated yttrium-oxide-partially-stabilized zirconia ceramic. The reason for choosing the Panavia F resin composite cement in the current study was that a previous study has shown that this luting agent can be used for restorations manufactured using zirconia ceramics [20]. This resin composite is also recommended by the manufacturer of the Denzir restorations.

The results obtained in the current study show that after luting there were no statistically significant differences (p > 0.05) in the marginal and internal gap width between the CAD/CAM-manufactured Denzir and the laboratory-made heat-pressed IPS Empress restorations. When Denzir and IPS Empress were compared with the other laboratory-made heat-pressed restorations studied, i.e. Opc, the latter showed a significantly (p < 0.001) wider gap width for the occlusal, gingivo-proximal and proximal measuring points than the two others. With respect to the internal fit there was no significant difference (p > 0.05) between Denzir and Opc or between Denzir and IPS Empress. Comparison between the two heat-pressed laboratory-made restorations, i.e. IPS Empress and Opc, revealed that the latter had a significantly wider internal gap width (p < 0.001). The laboratory-made heat-pressed restorations in the current study were made by student dental technicians during their training. However, the student dental technicians worked under supervision of an experienced certified dental technician and the inlays were finally examined and judged by an experienced dentist to be acceptable for permanent placing in patients as in clinical use. One Opc inlay was produced by another student dental technician. The fit of this inlay did not significantly differ from the nine other and, thus, did not skew the results obtained for the Opc restorations. The CAD/CAM-system studied requires impressions and diestone models [11]. That is, the outcome is influenced by those factors. Comparison of the internal fit when the restorations were placed on their matching die-stones and on their matching teeth before luting revealed that the internal gap width of the latter was significantly wider for Opc (p < 0.001) and Denzir (p < 0.01). A possible explanation can be that the dimension of the diestones and/or impressions was influenced during setting. Another explanation can be that minor irregularities in the surfaces of the ceramics made it difficult to properly seat the restorations on the premolars.

In a study by Sertgöz et al. the luting composite thickness of IPS Empress and CAD/CAM-manufactured (Cerec, software C.O.S. 2.0) inlays was studied [2]. The mean thickness of the occlusal and internal areas determined for the IPS Empress was lower than the values obtained for IPS Empress in the current study, whereas the proximal was wider. For Opc and the CAD/CAM-manufactured Denzir there are no previous data concerning the marginal and internal fit available. Therefore, the CAD/CAM-manufactured Cerec in the study by Sertgöz et al. [2] and the CAD/CAM-manufactured Denzir in the current study were compared. The occlusal and internal values were lower for the CAD/CAM-manufactured Denzir in the current study than the values for the CAD/CAM-manufactured Cerec inlays in the study by Sertgöz et al., whereas the values for the proximal gap were wider. It is uncertain whether these differences are statistically significant because there is a wide range of measurements in the standard deviations. In an in vitro study of IPS Empress inlays by Audenino et al. the marginal precision of those inlays averaged less than 50 microns after luting using a resin composite [4]. The different results obtained in the studies may have been caused by the fact that the number and location of the measuring points vary and that different luting agents and measuring techniques have been used. A previous study using techniques and similar numbers and location of measuring points similar to those in the current study is an in vitro study of four different ceramic inlays, Cerec, IPS Empress, In-Ceram, and Celay [8]. The results

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Internal*</th>
<th>Proximal*</th>
<th>Gingivo-proximal*</th>
<th>Occlusal*</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPS Empress</td>
<td>206 ± 60 (15–475)</td>
<td>153 ± 40 (35–735)</td>
<td>167 ± 30 (50–510)</td>
<td>147 ± 45 (40–425)</td>
</tr>
<tr>
<td>Opc</td>
<td>278 ± 128 (85–690)</td>
<td>246 ± 93 (50–555)</td>
<td>265 ± 121 (50–555)</td>
<td>256 ± 94 (60–740)</td>
</tr>
</tbody>
</table>

* Definition of measuring points in accordance with Figs. 1 and 2(a–d); Internal = measuring points A–G; Proximal = measuring points H–N; Gingivo-proximal = measuring points I–M; Occlusal = measuring points O–T.
obtained in the previous study [8] and the current study can therefore be compared to each other. Between the IPS Empress restorations in the previous [8] and the current studies the differences were not found to be statistically significant, with the exception of the occlusal gap width that was significantly wider in the current study ($p < 0.05$; ANOVA and Scheffe’s test). When Denzir was compared to the copy-milled Celay inlays in the previous study [8] there was no significant difference for the occlusal measuring points. For the internal fit the values obtained for Celay were significantly lower, whereas the values for the proximal and gingivo-proximal measuring points were significantly wider than for Denzir ($p < 0.05$; ANOVA, and Scheffe’s test). Comparison of the CAD/CAM-manufactured Cerec in the previous study [8] and the CAD/CAM-manufactured Denzir in the current study revealed that there was no significant difference in the internal fit, whereas the occlusal, proximal, and gingivo-proximal gap widths were significantly wider for Cerec than for Denzir ($p < 0.05$; ANOVA, and Scheffe’s test). In this context it has to be noted that the operating system for Cerec in the previous study [8] and in the study by Sertgöz [2] was C.O.S. 2.0 and that this system was later improved [1,3,21].

Martin and Jedynakiewicz reported in an in vitro study of Cerec restorations manufactured using the improved version (C.O.S. 4.2) that after luting the external interface gap was $50 \pm 15 \, \mu m$ for the occlusal walls, $143 \pm 47 \, \mu m$ for the internal occlusal floor, and $127 \pm 50 \, \mu m$ for the internal axial walls [1]. No statistically significant difference in the gap width between the three different cements used was seen [1]. However, the measuring techniques and the location and number of the measuring points were different in the study by Martin and Jedynakiewicz and in the studies of the Cerec and Decim restorations.

A disadvantage with Denzir is that the preparation of the cavities has to be made wider than for IPS Empress and Opv and that the lingual cusp has to be cut at a height of about 1 mm because the milling technique requires this preparation design. The Denzir restorations are also relatively difficult to grind and polish. However, in a preparatory study the occlusal marginal gap of ceramic inlays manufactured using conventional sintering on refractory dies was evaluated. An interesting observation in this preparatory study was that grinding and polishing after luting of those ceramic inlays seemed to cause irregular fractures at the occlusal margin of the inlays. At certain locations gap widths around 1 mm could be seen. The fractures at the margin were difficult to observe with the naked eye after polishing of the luting agent and of the ceramic inlays but were clearly visible after staining when examined using the measuring microscope.

5. Conclusions

After luting there were only slight differences in the fit between the restorations fabricated using the three different manufacturing techniques and ceramics. The clinical significance of the differences in marginal and internal fit in the current study is therefore difficult to predict. It has been shown in vitro studies that a wider resin composite cement gap can have certain advantages, whereas other studies have shown that certain shortcomings are related to wide interfacial gaps [5,18,19,22–24]. Long-term follow-up studies are therefore necessary for assessment of the clinical advantages and disadvantages of the various manufacturing techniques and ceramic materials.

References


