Evaluation of internal adaptation in ceramic and composite resin inlays by silicon replica technique

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SUMMARY This study was aimed at investigating the internal adaptation of a ceramic (Ceramco II) and two composite resin inlay materials (SureFil and 3M Filtek Z 250 TM) using silicon replica technique as an indicator. Forty-five standard mesial–occlusal–distal (MOD) cavities were prepared into brass moulds by using computer numerically controlled system. Inlays were prepared according to manufacturers’ instructions with indirect methods. Replicas of the prepared cavities and inlays were produced with a polyvinyl siloxane material (Elite H-D). The spaces between inlays and cavities were filled by different coloured light-body polyvinyl siloxane material. Two parallel slices (mesio-distally) were obtained from the replicas with a sharp blade. Different coloured polyvinyl siloxane material thickness between cavity and inlay was measured at seven points (mesial, occlusal and distal). The data were evaluated with ANOVA and Tukey’s honestly significantly different (HSD) statistical tests. In the SureFil and Ceramco II groups, the sizes of the contraction gaps at mesial and distal gingival floors were greater than that of the occlusal marginal walls. In comparison of gap formation at occlusal regions, while the 3M composite group showed highest gap values (204±33 ± 51±95 µm), the Ceramco II group revealed the lowest (141±17 ± 23±66 µm) (P < 0.05). At the gingival floors, gap formation of Ceramco II group was the highest (227±08 ± 51±95 µm). Neither the 3M Filtek Z250 nor SureFil group showed any statistical difference between gap values of their self-occlusal and gingival floors (P > 0.05). In conclusion, our results showed that ceramic inlays did not confer any big advantage for internal adaptation over the composite inlays.

KEYWORDS: inlay, silicon replica technique, internal adaptation

Accepted for publication 8 July 2004

Introduction

The use of composite resin for large posterior restorations presents several problems such as (i) difficulty in achieving adequate contact, (ii) difficulty in gaining access to the polymerization light in deep proximal zones, and (iii) the forces exerted by polymerization is reduced as the focal point is moved further from the light. For these reasons, techniques that enable extra-oral curing of composite resins have been investigated (1). However, a number of factors affecting the fitness of indirectly fabricated composite inlays have been reported including material type, age of restoration of die spacers used, finishing techniques, cement type and preparation design.

The indirect fabrication of resin composite restorations allows the material to be polymerized outside the mouth. In this way in situ shrinkage might be reduced, which could positively affect the reduction of gap formation and post-operative sensitivity (2–7). Moreover, the use of resin composites such as luting cements for porcelain or resin composite inlay restorations reduces the adverse effects of bulk polymerization contraction of posterior resin composite restorations because the volume of resin used in bonding the inlay is reduced (8–10).
The longevity of the indirect restoration may be influenced by both the overall thickness of the luting agent and the quality of marginal adaptation, where a minimum cement film thickness is desirable. Marginal seal plays the more important role in determining resistance to microleakage and resultant secondary caries. However, it is necessary to achieve good, overall three-dimensional fit for the restoration to receive maximum mechanical support from the underlying tooth, especially for occlusally loaded posterior teeth. In addition, it has been reported that significant stresses may be generated in the composite luting cement layer because of polymerization shrinkage which may, in turn, have a deleterious effect on the bond. This is true for both ceramic and composite indirect restorations (11–13).

A number of methods of assessment of both three-dimensional and marginal fit of indirect restorations have been described. Most in vivo studies have been directed towards the measurement of marginal accuracy using mirror and probe, and radiographic techniques. Indirect measurements have been made using models taken from restored teeth for subsequent assessment by visual and tactile methods and by optical and scanning electron microscopy. Additionally, overall three-dimensional fit has been assessed using an elastomeric impression washing place of the luting cement. Such replicas may subsequently be examined by mounting and sectioning or, alternatively, by visual inspection of the differential translucency of the wash material.

In this study, the internal adaptation of ceramic inlay restorations was compared to two composite inlay restorations by observing the interfacial gap between restoration and cavity walls using silicon replica technique.

Materials and methods

Forty-five simulated mesial–occlusal–distal (MOD) cavities were cut in brass moulds using a computer numerically controlled system.* The dimensions and shapes of the standard cavities were shown in Fig. 1 (diameter 9.0 mm; occlusal depth 2.5 mm; approximal depth 5.0 mm; occlusal width 3.0 mm and total taper 10°). After preparing the cavities, impressions of the brass-mould MOD cavities were taken with polyvinyl siloxane material (Elite H-D).† The impressions were poured with type II stone and separated from the dies after 1 h. The dies were coated with separating medium and inlays fabricated according to manufacturers’ instructions with indirect methods. The materials tested in the study are listed in Table 1.

An orange colour light-bodied, silicone impression material (Elite H-D) was used to construct replicas of the space between the inlays and the prepared cavities. Freshly mixed impression material was placed into each cavity. The inlay was then positioned into the preparation with gradually increasing finger pressure. In order to obtain standard pressure until setting of the materials, a 200-g weight was placed onto the inlay until the impression material had fully set and the excess was then removed. After constructing the replica of the space between the inlay and the prepared cavity by the orange colour light body, the replica was carefully peeled from the inlay. But it stayed on the mould and the empty place of inlay was replaced by a green colour light body silicon impression material. After setting this layer, the brass mould was removed from under the orange replica and was again replaced by the green colour light body silicon. Three increment replicas (inlay, space between inlay and cavity wall, and cavity) were obtained and the specimens were easy to cut and the thickness of orange colour replica easy to measure.

Different coloured (orange) polyvinyl siloxane material thickness between the inlays and the prepared cavities in the sectioned replica samples was measured.

*Emco, Hallein, Austria.

†ELITE H-D, Zhermack S.p.A., Badia-Polesine, Italy.
microscopically at seven points (two mesial, three occlusal, and two distal floor) using a micrometer under a stereomicroscope‡ (×20 magnification). The average of the measurements at three points (mesial, occlusal and distal) was calculated for each sample.

Statistical analysis

The gap values at gingival and occlusal floors of three experimental restoration groups were analysed and compared by one-way ANOVA and Tukey’s honestly significantly different (HSD) tests.

Results

The measured mean thickness and standard deviations of replica film representing the space between the inlay and the prepared cavity of each sample is presented in Table 2.

In the SureFil and Ceramco II groups, gaps at the gingival floors were greater than those of occlusal floor. The lowest gap formation was recorded at the occlusal regions of ceramic inlays (141·17 ± 23·66 μm). But in the 3M Filtek Z250 composite group, the occlusal gap value was the highest (204·33 ± 75·45 μm) (P < 0·05). At the gingival floors, the size of the contraction gaps was the highest in ceramic inlays (227·08 ± 51·95 μm) (P < 0·05). The comparison of occlusal gap values in composite groups indicated that the 3M Filtek Z250 group showed higher gap values than SureFil, but at the gingival floors there was no statistically significant difference between two composite groups (P > 0·05). Neither the 3M Filtek Z250 nor the SureFil group showed any statistical differences between gap values of their self-occlusal and gingival floors (P > 0·05).

Discussion

In this study, two types of inlay materials which are frequently used in dental clinics were compared according to their gap formation between cavity walls and inlay restorations by using the silicon replica technique.

It is generally accepted that marginal integrity is an important factor for the long-term success of inlays. The long-term clinical performance of inlays depends on a number of factors of which marginal adaptation is of significant interest (14). However, it is necessary to achieve good, overall three-dimensional fit for the

Table 1. Materials used in the study

<table>
<thead>
<tr>
<th>Materials</th>
<th>Composition</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>SureFil</td>
<td>Silica and barium fluoro alumino borosilicate glasses, urethane-modified bis-GMA, particle size 0·8 μm, filler loading 65% by volume</td>
<td>Dentsply, Caulk, Mildford DE, USA</td>
</tr>
<tr>
<td>3MFiltek Z 250</td>
<td>Zirconia/silica, Bis-GMA, UDMA, Bis-EMA, particle size 0·01–3·5 μm, inorganic filler loading 60% by volume</td>
<td>3M Dental Product, St Paul, MN, USA</td>
</tr>
<tr>
<td>Ceramco II</td>
<td>Felspathic porcelain (in %): SiO₂ 59·2, Al₂O₃ 18·5, Na₂O 4·8, K₂O 11·8, B₂O₃ 4·6, ZnO 0·58, ZrO₂ 0·39</td>
<td>Ceramco Inc., Burlington, NJ, USA</td>
</tr>
</tbody>
</table>

Table 2. The mean thickness and standard deviations of the gingival and occlusal gap formation of each material (n = 30)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Gingival floor [mean ± s.d. (μm)]</th>
<th>Occlusal floor [mean ± s.d. (μm)]</th>
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restoration to receive maximum mechanical support from the underlying tooth, especially for occlusally loaded posterior teeth (11). For conventional (non-adhesive) inlay restorations, the smallest possible gaps are required between cavity walls and the restoration. This was also postulated for adhesive-luted aesthetic inlays, in the expectation that with the small volume of luting composite, stress caused by polymerization shrinkage would be reduced. Schmalz et al. (15) found in their study that with a luting space up to 100 μm, the width of the luting space has no influence on the marginal quality. In our study, luting space after polymerization shrinkage was found to be over 100 μm for all tested materials. Therefore care should be taken during selection of material for cementation.

Inlay under hangs appeared to be the most frequent marginal inlay defect, both occlusally and interproximally. If this overhangs and under hangs is high, they will represent the most unfavourable situation for gingival and periodontal health (16). Moreover it can be concluded that inlay adaptation is more related to manipulation by the fabricator than to the ceramic or fabrication materials themselves. In this study, marginal and overall adaptation of inlays by using silicon replica technique was evaluated within cementation to observe the sealing gap and the morphology of inlay margins without any imprecision and artifacts caused by overfilling of the luting material.

Some studies have recommended a fitness-checking medium to assess fitting the accuracy of gold crowns and metal ceramic crowns (11, 17). Originally, a thin film of zinc oxide and eugenol impression paste was used as the indicating medium. Later, the technique was modified by the use of a syringe-type silicone impression material by McLean and von Fraunhofer (18). Campagni (19) also described a clinical technique for improving the adaptation of castings with the silicone impression material. Internal adaptation of inlays must first be verified on master dies, as it is difficult to evaluate adaptation inaccessible between-cavity walls and restoration spaces, with an explorer. The use of a silicone fitness-checking medium provides verification of fitness in-between cavity walls and restorations.

Other laboratory methods may also provide useful information about internal fitting accuracy but generally involve sectioning restored units and are therefore destructive. Such methods of assessment are also limited to measurements on the exposed planes. An interesting, non-destructive approach has been taken by Freijlich et al. (20), who described the use of moiré topography to assess the dimensional accuracy of acrylic resin complete denture bases. The reproducibility of their experimental set-up was up to 25 μm, and results were in close agreement with average fitness measurements determined by the impression wash technique. The latter still remains the standard against which other non-destructive methods may be compared. To date, no comparison has been carried out between fitness measurements obtained from destructive sectioning techniques and non-destructive impression washes. In this study, a modified silicon replica technique was used, because in this technique overall three-dimensional fitness was assessed by measuring the thickness of silicon replicas of elastomeric impression washing place of the luting cement.

Qualtrough et al. (11) indicated in their study that the use of silicon impression material to indicate the gap between restoration and prepared tooth surface may not replicate exactly the behaviour of dental cement in the clinical situation. However, the choice of a low-viscosity silicone paste should reduce this source of error as far as absolute values are concerned and as long as relative differences remain meaningful. Such silicon replicas may also be examined by mounting and sectioning without destruction of original specimen. As different gap measurement methods were used in the other studies, the gap values of indirect restorations showed differences. The gap values were found to be higher in this study than those of some other studies (21, 22). We speculate that this is because of the difference in gap measurement technique.

In this study, maximal occlusal gap varied in the specimens from 141-17 μm for ceramic inlays to 204-33 μm for 3M Filtek Z250 and maximal proximal gap varied from 185-00 μm for SureFil to 227-08 μm for ceramic inlays. The fitness of inlays was poorer at approximal margins because of inaccurate inner fitness. In general, marginal adaptation differed significantly between the composite and ceramic inlay systems. While the ceramic inlays produced the highest marginal gap values in the gingival margins, the composite groups showed thicker gaps at the occlusal margins of restorations. This was attributed to the fact that polymerization shrinkage of composite resin occurred towards the light source which was coming from occlusal surface at the beginning of curing.

Qualtrough et al. (11) determined the fitting accuracy of composite inlays (Brilliant, SR-Isosit, Occlusin, and
Herculite) by using sectioning of replicas as in our study and the gap values were reported to be in the range of 71.4–257.5 µm. Similarly, in the present study, the sectioned replicas showed gap values in the range of 141.17–227.08 µm.

In an investigation about cavity adaptation of composite inlay by Qvist (21), the average width of the intermediate resin was 150 µm (range 50–270 µm). Our results were slightly higher those of Qvist (21). The average width of the space between the composite inlays and the prepared cavity in the sectioned replica samples were 185.00 ± 74.72 µm and 197.91 ± 72.61 µm in gingival regions and 173.83 ± 70.95 µm and 204.33 ± 75.45 µm in occlusal regions in this study, respectively. In a previous study, marginal gap formation was microscopically investigated on brass moulds and the mean gap formation value was 73.86 µm for porcelain inlay, 83.86 µm for composite inlay and 15.76 µm for amalgam restorations (22). The difference between the gap values of composite and porcelain inlay group was not statistically significant, but the difference between amalgam and inlay group was statistically important. Marginal gap formation values for both composite and porcelain inlays were lower than those of the present study. We speculate that the dissimilar results of our two studies are due to differences in measurement techniques. But when the microleakage values of the same materials were compared in another study (23) it was found that they did not change according the materials used. One possible explanation for this is that the inlay restorations were adapted to the cavities with luting cements, and the behaviour of cement played an important role in preventing microleakage. The results of the previous studies (1, 2, 5) suggest that marginal or internal adaptation studies can give more reliable results than microleakage studies during investigation of cavity-restorative material integrity.

Dietschi & Moor (24) evaluated of the marginal and internal adaptation of different ceramic (In-Ceram and Duceram) and composite inlay (Tetric) systems after an in vitro fatigue test and they also reported the clear advantages of analysing both external and internal adaptation of adhesive restorations.

In this study, it was found that the high-density posterior composite material, SureFil, showed less gap formation than the hybrid composite material 3M Filtek Z 250. Thus, the authors recommend that high-density packable composite materials are preferable for the production of composite resin inlays in clinical situations.

In conclusion, ceramic inlays gave no significant advantage for internal adaptation over the composite inlays, and also our results of silicon replica technique suggest that the evaluation of internal adaptation produced meaningful information about the potential of restorations to resist leakage, while the observation of the internal interfaces helped localize and understand deficiencies still existing in the adhesive procedures tested. However, more accurate and non-destructive methods are still needed to evaluate the internal adaptation of restorations.

Acknowledgments

The authors are grateful to ceramic technician Ahmet Seven for his technical assistance and help.

References


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