The fit of gold inlays and three ceramic inlay systems

A clinical and in vitro study

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Four inlay systems—gold, Cerec, Mirage, and Empress inlays—were evaluated for their adaptation to stone die and clinically to the tooth by means of a replica technique. Twenty inlays of each system were placed on premolars and molars in the lower jaw. A microscope was used to measure the adaptation at the approximal margin, at the inner axial wall, and at the occlusal cavosurface area. An overall better fit was observed for the gold inlays than for the ceramic inlays. When the different measuring locations were compared, a better fit was found for the occlusal area. The greatest discrepancies were recorded for the Cerec inlays, whereas the Mirage and Empress inlays were comparable. □ *Ceramics; dental materials; dental porcelain, inlays*

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Modern techniques in restorative dentistry include the use of ceramic materials in crowns, laminates, onlays, and inlays. The development and use of new ceramic materials in combination with adhesive techniques has resulted in more frequent use of these materials in more extensive oral prosthetic rehabilitations. Several ceramic systems have been developed, and patients frequently request tooth-colored restorations for esthetic reasons and as alternatives to metallic restorative materials. Porcelain is biocompatible and has excellent esthetic properties, but its clinical long-term outcome has not been convincingly evaluated and/or reported. One important variable concerning longevity is the fit of the restoration to the tooth and, in particular, the marginal fit (1–3). A marginal inaccuracy might be a serious drawback, predisposing to the failure of the restoration.

Today there are mainly three modes of manufacturing ceramic inlays: conventional sintering techniques, fabrication by a casting or pressure technique, and, finally, different kinds of direct milling techniques. The first two techniques require an impression and a model of the prepared tooth. Furthermore, for the sintering technique a refractory die must be manufactured. These steps in the manufacturing process may result in deviations from the desired accurate fit of the inlay on the tooth. When the direct milling techniques are used, an optical recording of the preparation is made when possible, and a die may be excluded.

The present study was aimed to assess quantitatively and compare the inner and marginal adaptation of four types of inlays: three ceramic systems and traditional gold inlays.

Materials and methods

The study comprised 20 patients, 11 women (mean age, 33 years; range, 23–48 years) and 9 men (mean age, 41 years; range, 23–56 years). They were selected after a general advertisement at the University of Oslo, which generated a group of 60 persons who were originally screened for participation. The finally selected group fulfilled the inclusion criteria, which were a history of class-II filling therapy performed on premolars and molars on each side in the man-

dibular jaw and a demand for alternative materials. Only one of the selected teeth had been endodontically treated.

All patients were treated with one gold inlay (Sjödings Type III) and three ceramic inlays, inserted in a randomly selected order in the lower jaw. In total, 35 premolars and 45 molars were treated with inlays. A limited number of the preparations included the buccal and/or lingual surfaces. The tooth preparation procedure was performed in accordance with general principles for gold and ceramic inlay therapy. The ceramic preparations had cervical shoulders, whereas the gold inlays had a sliced approximal finishing line. The occlusal cavosurface margin was approximately 90°. All clinical treatments were performed by one of the authors (M. Molin).

Full arch impressions were taken in an A-silicon material (President, Coltène, AG, Alstätten, Switzerland). Stone dies (Bayer Moldastone) were poured within 4 h by one of the laboratories. The ceramic inlays were manufactured in accordance with three different techniques: designing the inlay with computer-aided design and milling the inlay out of a ceramic block (Vita Cerec, Vita Zahnfabrik, Säckingen, Germany) by computer-aided manufacturing methods (CAD/CAM) (Cerec, Siemens AG, Bensheim, Germany), conventional porcelain build-up sintering technique (Mirage, Myron, Kansas City, USA), and a glass ceramic casting high-pressure technique (Empress, Ivoclar, Amherst, N.Y., USA). One dental laboratory produced the Mirage and gold inlays and another the Empress inlays.

Owing to limited space for the camera, an intraoral optical impression of the tooth was impossible in some cases. Therefore, to standardize the procedure, the Cerec inlays were manufactured after an optical reading of the stone dies. The dental laboratories were informed about the purpose of the study. In total, 80 inlays were investigated for inner and marginal fit. All clinical procedures were standardized and identical up to and including the production of the stone dies.

When the inlays were returned from the laboratory for a try-in procedure, replicas were made of the intermediate space between the inner surface of the inlay and the stone die surfaces. This was achieved by coating the stone die cavity walls with a thin layer of light-body A-silicon material (President, Coltène), after which the inlay was placed onto the stone die and finger-pressure applied. After setting of the impression material the inlay was removed, leaving a thin film of light-body material adhering to the die, representing the discrepancy between inlay and stone die. For the purpose of stabilization, a heavy-body material (President, Coltène) was applied, adhering with the light-body film dressing the cavity. This procedure made it possible to remove and handle the intermediate replica of the light-body material. The same procedures were applied for the clinical intraoral replica production of the inlay versus the prepared tooth. No adjustments were performed either of the prepared tooth or of the inlay before taking the replica.

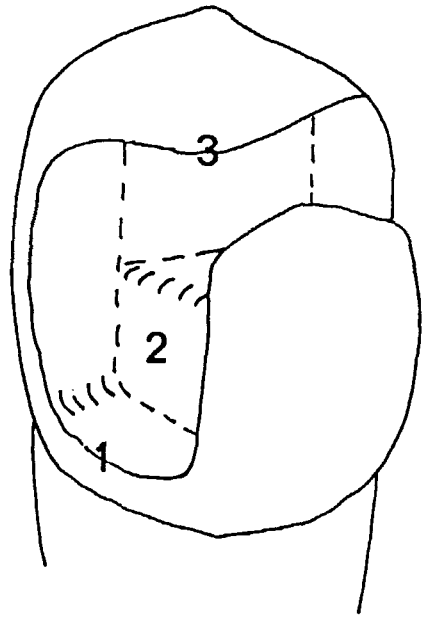

Fig. 1. Measuring locations: 1 = marginal area; 2 = axial wall; 3 = occlusal area.

The replica specimens were sectioned with a scalpel in two axial directions, buccolingually and mesiodistally, resulting in four pieces. A microscope (Nikon Profile Pro-

jector) was used at 50× magnification for measurements. All registrations were made to the nearest 1 μm. Measurements of the film thicknesses were performed at three different locations and at six points—that is, at the mesial and distal approximal margin, the inner medial axial walls, and the occlusal cavosurface margin—resulting in four measurements of each location and totaling 24 measurements for each replica (Fig. 1). At the margin, the film thickness was measured as the shortest distance between the edge of the inlay and the tooth structure (4). Measurements along the axial wall were performed at approximately half the distance between the bottom of the cavity and the occlusal border, perpendicular to the surface and at a representative area. In total, 5760 measurements were made.

To assess the precision of the method, double estimations were made of 40 locations. The mean difference between pairwise measurements was 4.9 μm ± 3.12 μm, and the coefficient of correlation $r = 0.96$.

A paired Student's t test (5) was used to find statistically significant differences between film thickness recorded for tooth and die stone, and ANOVA was used for observed differences between the inlay methods.

This study was approved by the Ethical Committee, University of Oslo.

Results

The recorded mean thickness of the replica film representing the marginal and inner accuracy of each systems is presented in Table 1. When all the inlay systems were compared, the thinnest mean marginal gap was recorded for the gold inlays at the occlusal location (30 μm; range, 0–153 μm) and the greatest for the Cerec inlays at the cervical margin (195 μm; range, 59–391 μm).

When the mean film thickness of the replicas taken on the die and on the tooth was compared, a significantly ($P < 0.01$) better fit was found on the die for locations 2 and 3 for the gold inlays, locations 1 and 2 ($P < 0.05$, 0.01) for Mirage, and location 1 ($P < 0.05$) for Empress inlays.

The measured mean film thicknesses, expressing the accuracy of the inlay systems examined, showed that the gold inlays in general had an overall significantly better fit to both the die and the tooth than the other ceramic inlay systems investigated ($P < 0.01$–0.001). Expressed in terms of thickness of the replica film or discrepancy between inlay and die/tooth, the following significant-principle order was established after analyses by ANOVA: gold inlays < Mirage/Empress < Cerec.

For all of the observed inlay systems the greatest discrepancy was recorded for location 2, the inner axial walls, followed

Table 1. Mean discrepancy between stone die prepared tooth and inner surface of the different inlays at three measuring points

Measuring point	Inlay system	Stone die, μm			Tooth, μm		
		Mean	SD	Range	Mean	SD	Range
1	Gold	48.9	34.2	0–115	57.8	37.9	0–173
	Cerec	195.4	95.7	59–391	155.3	106.9	32–369
	Mirage	84.7	64.4	0–279	128.0	108.7	0–407
	Empress	65.4	59.0	0–256	114.7	105.2	0–469
2	Gold	63.8	32.9	18–173	94.5	51.8	0–266
	Cerec	177.1	84.7	44–332	160.3	97.0	0–384
	Mirage	88.2	2.4	0–306	144.0	109.5	38–505
	Empress	121.8	97.5	0–626	139.7	81.4	21–326
3	Gold	29.9	37.9	0–153	57.1	40.6	0–193
	Cerec	131.4	92.3	0–355	123.4	87.0	0–369
	Mirage	51.6	53.6	0–261	48.5	53.9	0–221
	Empress	65.7	70.0	0–427	93.8	69.4	0–413

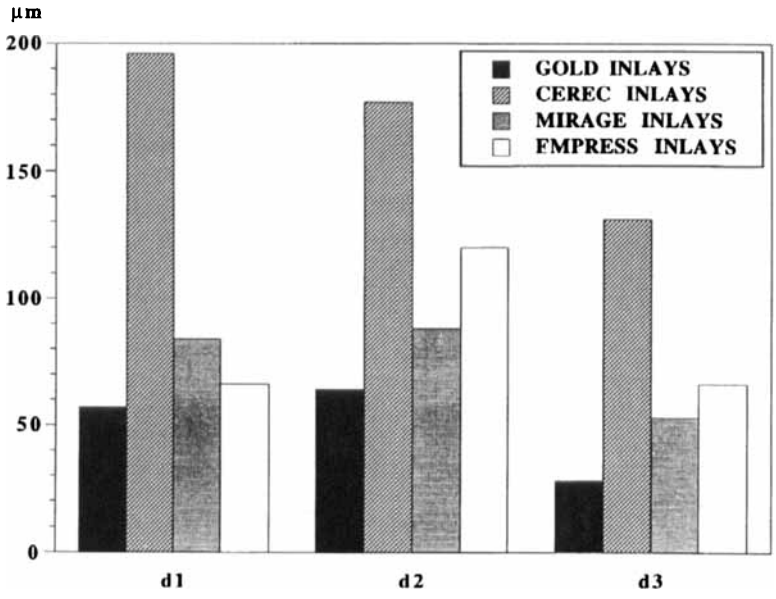

Fig. 2. Mean film thickness on the die for different inlay systems. d = stone die; 1, 2, 3 = measuring locations in accordance with Fig. 1.

by the cervical and the occlusal measuring points (Fig. 2).

Only one significant difference ($P < 0.01$), location 2, die, with regard to measured mean thickness of the film was found when the Empress and the Mirage inlays were compared. The adaptation to the die was significantly ($P < 0.001$) better for these two ceramic systems than for the Cerec inlays.

Discussion

An in vivo assessment of restoration–tooth discrepancy will result in some inherent methodologic errors related to the replica material and to the method of measurement. These drawbacks have, however, been discussed and accounted for earlier (1, 6). Likewise, repeated measurements in this study were closely correlated.

The adaptation of the inlay to the die, expressed in terms of the measured thickness of the intervening film, was in most cases better than the fit on the tooth. This difference could mainly be explained as a consequence of making an impression and a master cast, handling procedures, and the use of materials that will introduce dimensional errors.

A wide range expressed in terms of standard deviation and range was observed for all measurements. Compared with a conventional crown preparation, an inlay preparation is more irregular with a great number of angles, resulting in manufacturing difficulties predisposing to inaccuracies. Several of the dies used for the production of the Mirage and Empress inlays were blocked for undercuts at the axial walls (location 2). This procedure will explain most of the great discrepancy observed at this location. For a conventional inlay preparation this area will correspond to the isthmus region, which by experience is prone to fractures (7). A thick layer of composite resin could be hypothesized to be unable to withstand the occlusal load and thus induce bending forces in the ceramic material. Furthermore, the magnitude of compression of a thick resin layer will be greater than that of a thin layer, and the resulting mechanical stress transferred to the ceramic inlay will be increased.

The marginal adaptation (location 1) differed significantly between the systems. The greatest marginal gaps were recorded for the

Cerec system, irrespective of location, and the smallest for gold inlays. A better fit for gold inlays was anticipated as a sliced finishing line will predispose to smaller marginal gaps than the shoulder preparations performed for the ceramic inlays.

The Cerec system had the greatest discrepancy at the approximal margin, which agrees with findings in other studies (8–10). This might be an indication that the process of optical reading of the preparation is more inaccurate when reading heights than when reading horizontal surfaces. It is not possible to predict the clinical significance of this difference, as clinical long-term investigations are missing.

In this study an optical impression of the stone die was performed; this procedure would theoretically increase the discrepancy compared with a reading of the tooth, advocated by Cerec. Nevertheless, the difference in accuracy between die and tooth can only to a limited extent contribute to the difference between Cerec and the other systems. In addition, the other two ceramic systems, Mirage and Empress, expressed similar accuracy on both die and tooth even though they are made with different manufacturing processes.

Some major concerns related to ceramic inlay therapy are their strength and marginal fidelity. Both factors probably affect the longevity of the restorations. For metallic cast crowns a marginal gap on the order of 100–150 μm has been reported to be in the range of acceptability (1, 3). However, the definition of fit has great variations depending on method and location of the measurements. Furthermore, empirical data and clinical experience describing the handling of gold restorations luted with phosphate cement are, rightly or wrongly, occasionally adopted for adhesively luted reconstructions. Nevertheless, imprecise inlays with marginal discrepancies will increase the risk for wear of the luting material, in particular in occlusal areas. In a previous in vivo study a substantial wear of the composite resin in the occlusal area was found 16 months after the insertion of Cerec inlays (11). A difference was also observed between different luting materials used. The present study showed an occlusal gap on the order of 30–148 μm. A scheduled follow-up examination of the same patients will further establish the clinical long-term significance of this discrepancy.

In addition, degradation of the material and marginal leakage may predispose to secondary caries and discoloration (12, 13).

Another potential problem may be a discrepancy influencing the bond strength of the resin to tooth substance and the ceramic inlay, making it prone to fracture with time. Induced internal stress due to differences in thickness of the resin layer might be another contributing factor (7). So far, there are no studies convincingly reporting the importance of the magnitude of this discrepancy. There are, however, some studies reporting a difference in the linear polymerization shrinkage when measuring the curing contraction for different layers of composite luting resins (14, 15). However, gold inlays luted with phosphate cements have been reported to have a satisfactory longevity (15, 16).

An 'ideal' range for the marginal gap when luting ceramic inlays with composite resin materials has, so far, not been reported. This variable, however, will probably be of great clinical importance for the longevity of ceramic inlays luted with bonded composite resins. The scheduled follow-up of the patients in the present study will, we hope, further establish the clinical significance of this variable.

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