Ceramic inlays (Cerec) cemented with either a dual-cured or a chemically cured composite resin luting agent

A 2-year clinical study

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On the basis of the criteria of the California Dental Association (CDA), 66 CAD/CAM-manufactured ceramic class-II inlays (Cerec) were compared intraindividually after they had been cemented with either a chemically cured or a dual-cured composite resin luting agent in 27 patients. Plaque and gingival conditions, the overall time consumption for producing each inlay, and the frequency of postoperative sensitivity were also evaluated. There was no statistically significant difference between the two luting agents with regard to the properties evaluated. One inlay was replaced owing to fracture of the restored tooth just before the 24-month re-examination. After 2 years excellent CDA ratings were obtained for color in 92% of the remaining 65 inlays. The corresponding figures for surface and for anatomic form were 100% and 85%, respectively. For margin integrity 85% of the 33 inlays cemented with the dual-cured luting agent and 88% of the 33 inlays cemented with the chemically cured luting agent were rated excellent after 2 years. □ *CAD/CAM; cementation; clinical evaluation; dental materials; dental porcelain*

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CAD-CAM-manufactured ceramic inlays have been available in dentistry since 1988, when the Cerec CAD-CAM system for dental restorations was introduced onto the market. During the past few years Cerec inlays have been evaluated in longitudinal clinical studies and in in vitro studies (1–4). As in most studies dealing with ceramic inlays, these have usually been cemented with dual-cured composite resin luting agents.

However, there is some doubt about the setting of dual-cured resin luting agents under restorations, since the setting of dual- and light-cured luting agents depends to a great extent on exposure time and the intensity of the light source (5–8). Ceramic attenuates light depending on its thickness and shade (5–7), and the chemically activated components in dual-cured luting agents do not provide complete hardening of the luting agent in those parts of a tooth not reached by the curing light. For example, Breeding et al. (7) have shown that the chemical curing in dual-cured composite resin luting agents can be incapable of compensating for inadequate light exposure and possesses limitations similar to light-activated luting agents. Moreover, in a study by Rueggeberg & Caughman (8) no evidence was found for a substantial chemically induced polymerization of dual-cure resins after light exposure is completed. Thus, the polymerization can be incomplete under thick ceramic restorations, and maximal support of the luted ceramic restorations is not obtained, since the ultimate hardness of dual-cured luting agents depends on the amount of exposure to the curing light.

The aim of the present study therefore was to compare Cerec ceramic inlays luted either with a two-component chemically cured or with a dual-cured composite resin luting agent in an intraindividual study.

Materials and methods

Sixty-six Cerec ceramic class-II inlays (Vita Cerec Mark II, Vita Zahnfabrik, Bad Säckingen, Germany) were manufactured, using the CAD/CAM technique (Cerec System, software C.O.S. 2.0, Siemens AG, Bensheim, Germany) in accordance with the manufacturer's instructions (9) by three dentists. The inlays were placed on molars or premolars in 27 patients who regularly visited Public Dental Health Service Clinics or Umeå University Dental School. The subjects, 17 female and 10 male patients, ranged in age from 15 to 65 years (mean, 37 years).

At the initial examination routine anamnestic records and any symptoms from the temporomandibular joint (TMJ), masticatory muscles, and oral mucosa were monitored.

Twenty-two of the patients received two inlays each, four patients four inlays each, and one patient six inlays. Thirteen molars, 4 of them second molars, and 53

premolars were restored. Fifteen inlays were 3-surface restorations on premolars and 2 were 3-surface restorations on molars, 38 inlays were 2-surface restorations on premolars, and 11 were 2-surface restorations on molars. The indication for the treatment was primary caries for 20 inlays and replacement of amalgam or composite fillings for the rest. In the latter cases the reasons for replacing the amalgam or the composite fillings were secondary caries or fear of side effects from the amalgam and, in one case, oral lichen planus.

The preparation design of the cavities was in accordance with the manufacturer's instructions (9). Dentinal areas near the pulp were protected with a calcium hydroxide base (Dycal, L.D. Caulk Co., Milford, Del., USA), and a glass-ionomer cement (Baseline, De Trey Dentsply, Konstanz, Germany) was placed as a base in very deep parts of the cavities and for blocking undercuts. To make it possible to analyze a potential influence of the preparation design in case of any fracture of an inlay, an impression of each prepared cavity was taken with an A-silicon (President, Coltène, Altstätten, Switzerland) or an alginate hydrocolloid (Algi-X, Svedia-Dental Industri AB, Enköping, Sweden), and stone die models were made (Kerr Vel-Mix Stone ISO Type IV, Kerr Europe AG, Basel, Switzerland). Fifty-four of the inlays were made directly and 12 indirectly on die stone models. The ceramic blocks used were Vita Cerec Mark II (Vita Zahnfabrik).

Before the inlays were luted, the enamel was etched with a 36% phosphoric acid gel, and the teeth were subsequently rinsed with water and dried with compressed air. A dentin bonding agent (Gluma, Bayer, Leverkusen, Germany) was placed on the dentin, followed by spraying with air. Enamel bonding agents used were those recommended by the manufacturers of the resins (Coltene Duo Bond Kit, Coltène, batch 9205-510, and Cavex Clearfil F2, Cavex Holland BV, RW Haarlem, Holland, batch 911001, respectively).

On a randomized basis half the number of the inlays in each patient were cemented with a two-component, dual-cured hybrid composite resin luting agent (Cerec Duo Cement, batch 9110-983) and the rest with a chemically cured hybrid composite resin luting agent that was primarily intended as a filling material for anterior teeth (Cavex Clearfil F2, batch 910415). Previously, the inlays had been etched with 4.9% HF acid for 1 min (Vita Cerec-Etch, Vita-Zahnfabrik) and silane-treated for 1 min (Ultradent Silane, Ultradent Products Inc., Utah, USA) in accordance with the manufacturers' instructions. To prevent excess of the luting agent at the proximal margins, plastic or metal strips and wooden wedges were used. For each restoration cemented with the Cerec Duo Cement the luting agent was light-cured by means of a dental photocuring lamp (ICI Model 4000, Imperial Chemical Industries PLC, Cheshire, England, or Norlite, Dencon GmbH, Bremen, Germany) for 60 sec each from the occlusal, buccal, and lingual/palatinal surfaces.

After being luted the inlays were contoured and adjusted in occlusion and articulation. Excess luting agent was removed with fine diamonds (Cerec-Set, 40 μm), and the restorations were polished with superfine diamonds (Cerec-Set, 15 μm), rubber polishers (Shofu Ceramisté, Shofu Inc., Kyoto, Japan), SofLex polishing discs (3 M Dental Product Division, St Paul, Minn., USA), and diamond paste (Ultradent Diamond polish, Ultradent Products Inc., Utah, USA).

The position of the cervical proximal inlay margins and the total time needed for manufacturing each inlay, including all the steps from preparation to luted and polished inlay, were recorded.

Evaluation

Two weeks after luting (*base line*) and after 12 and 24 months the patients were recalled, and the inlays were examined in accordance with the California Dental Association's (CDA) quality evaluation system (10) after calibration of four evaluators, working in pairs but independent of each other. The surface and color, anatomic form, and marginal integrity were evaluated. Whenever disagreements occurred, the two evaluators resolved them by joint examination. At each recall the patients were also interviewed for postoperative sensitivity, in accordance with the system used by Borgmeijer et al. (11).

In addition, at the 24-month re-examination plaque and gingival conditions were registered by one of the examiners. The plaque and bleeding indices used were in accordance with Lenox & Kopczyx (12). Surfaces with Cerec inlays were compared with surfaces without Cerec restorations on adjacent teeth. Molars were always compared with molars and premolars with premolars. When the adjacent tooth was lost or was unsuitable for other reasons, such as being provided with a temporary restoration, the control tooth had to be chosen in other quadrants. Corresponding surfaces were always compared with each other; for example, a mesial Cerec inlay surface was compared with the mesial surface of the control tooth.

Statistical analysis

The values obtained for the CDA scores both for the occurrence of shallow marginal ditching and for the plaque and gingival conditions for each type of luting agent were analyzed statistically, using the test of difference of proportions.

Results

The initial clinical examination showed that one patient had clicking sensations from the TMJ and three patients had tenderness on palpation from the masticatory muscles. Ten patients had tooth wear rated grade II–

Table 1. Percentages and numbers of inlays that did *not* receive an excellent CDA rating* for margin integrity, anatomic form, color, and surface ($n = 33$ for each group, with the exception of the dual-cured luted inlays in the groups anatomic form, color, and surface at the 24-month re-examination, $n = 32$, since one inlay had been replaced by a crown)

	Dual-cured						Chemically cured					
	Base line		12 months		24 months		Base line		12 months		24 months	
	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Margin integrity												
SDIS			3	1	9	3			3	1	6	2
SCR	3	1	3	1	3	1					3	1
VFR											3	1
VTF					3	1						
Anatomic form												
SCO	6	2	6	2	3	1	3	1				
SPX	3	1					3	1				
SUCO							6	2	9	3	6	2
SOCO	6	2	6	2	6	2	6	2	9	3	6	2
SMR			3	1	3	1			3	1	3	1
SOH			3	1	3	1						
Color												
SMM	9	3	6	2	9	3	9	3	6	2	6	2
Surface												
SRO									3	1		

* SDIS = discoloration on margin between the restoration and the tooth structure; SCR = visible evidence of ditching along the margin not extending to the dentinoenamel junction; VFR = fracture of the restoration; VTF = tooth structure fractured; SCO = contact slightly open (may be self-correcting); SPX = interproximal cervical area slightly undercontoured; SUCO = restoration is slightly undercontoured; SOCO = restoration is slightly overcontoured; SMR = marginal ridges slightly undercontoured; SOH = occlusal height reduced locally (not in toto); SMM = slight mismatch between restoration and tooth structure within normal range of tooth color, shade, and/or translucency; SRO = surface of restoration is slightly rough or pitted, can be polished.

III in accordance with the rating system suggested by Eccles (13). No changes were observed during the follow-up period.

No statistically significant difference was observed between the two luting agents used with regard to the properties evaluated. Frequencies of the CDA scores for the evaluated factors are given in Table 1.

All inlays were rated satisfactory at each examination by means of the CDA rating system, with the exception of two inlays at the 24-month re-examination. One of those inlays was rated VFR (fractured restoration) and the other was rated VTF (tooth structure fractured). The latter inlay had been replaced with a ceramic crown just before the 24-month re-examination owing to fracture of the restored tooth.

With regard to margin integrity, 85% of the inlays cemented with the dual-cured luting agent and 88% of the inlays luted with the chemically cured luting agent were rated excellent at the 24-month re-examination (Table 1). However, when the margins were examined

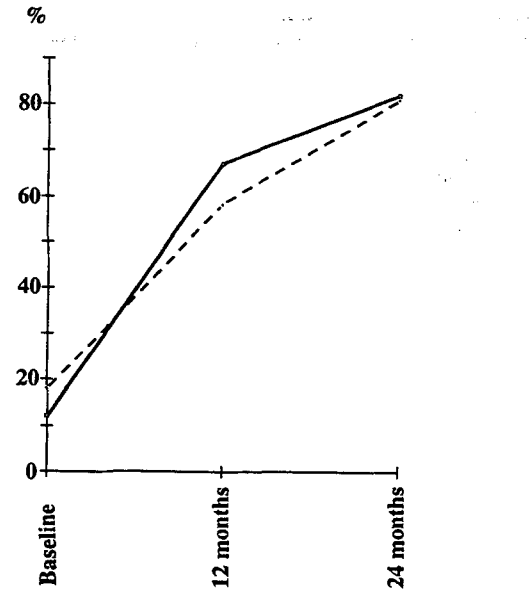

Fig. 1. Percentage of inlays with ditching at the occlusal margins; $n = 33$ at each examination with the exception of the inlays cemented with the dual-cured luting agent at the 24-month re-examination, at which $n = 32$ owing to fracture of a lingual cusp. Broken line = dual-cured; continuous line = chemically cured.

with an explorer, the explorer did not stick but registered differences in height because of shallow ditches around the occlusal margins of the inlays (Fig. 1). As can be seen in Fig. 1, the number of inlays with clinically detectable occlusal margins increased during the follow-up period, but these inlays still fulfilled the requirements to be rated 'excellent' with regard to margin integrity according to the CDA rating system. At the proximal and cervical margins no wear of the luting agent could be detected when examined with an explorer. No clinical evidence of marginal caries was seen in any of the inlays after 24 months.

The interexaminer agreement for the CDA quality rating exceeded 85% at each examination.

Six patients showed postoperative sensitivity related to one of their inlays (9% of the inlays). Two patients reported sensitivity to heat and cold lasting 1 or 2 weeks, and one reported such sensitivity lasting for a couple of days. The three teeth concerned had been exposed to excessive polishing at the cervical margins during removal of excess luting composite. One patient reported sensitivity on loading lasting for a couple of days, one patient reported sensitivity to heat and cold that remained at the 12-month re-examination, and another patient reported occasional sensitivity both to cold and on loading, still remaining at the 24-month re-examination. Three of the teeth that showed postoperative symptoms had inlays cemented with the dual-cured luting agent and three of them had been cemented with the chemically cured luting agent.

Table 2. Margin index score* of Cerec proximal surfaces

Dual-cured					Chemically cured				
Surface	Score 0	Score 1	Score 2	Score 3	Surface	Score 0	Score 1	Score 2	Score 3
Base line					Base line				
Mesial ($n = 16$)		1	6	9	Mesial ($n = 15$)			5	10
Distal ($n = 25$)		3	9	13	Distal ($n = 27$)		2	9	16
12 months					12 months				
Mesial ($n = 16$)	1	1	5	9	Mesial ($n = 15$)			3	12
Distal ($n = 25$)		3	8	14	Distal ($n = 27$)		2	9	16
24 months					24 months				
Mesial ($n = 15$)†		1	4	10	Mesial ($n = 15$)			3	12
Distal ($n = 24$)†		1	9	14	Distal ($n = 27$)		2	10	15

* 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.
† One inlay had been replaced with a crown owing to fracture of the lingual cusp.

Even though some of the patients in the present study had parafunctional habits (tooth grinding, tooth clenching) and had first and second molars treated with Cerec inlays, none of the 66 inlays fractured during the follow-up period, with the exception of a minor chip fracture at the margin of one of the inlays. This was easily adjusted, and the inlay is still functioning. In addition, the lingual cusp of one of the restored premolars was fractured just before the 24-month re-examination, and the inlay had to be replaced with a ceramic crown.

Most of the Cerec inlays had margins placed subgingivally or at the level of the gingival margin. No systematic changes of the level of this margin were observed during the follow-up period (Table 2). At the 24-month re-examination proximal plaque and bleeding on probing were not seen more often on Cerec inlay surfaces than on the corresponding surfaces of the control teeth without Cerec inlays, and no statistically significant difference was observed between the two luting agents used (Table 3).

The average total time taken to make the Cerec class-II inlays was 1 h and 50 min (range, 1 h to 2 h and 30 min), and there was no systematic difference in the time taken between restorations produced directly and those produced indirectly. All the inlays placed on second molars had been produced indirectly, since there was limited space for the miniature video camera when the rubber-dam was seated. They also needed the longest time, not because they were manufactured indirectly but because they were replacements for fairly large amalgam fillings.

Discussion

The luting technique for ceramic inlays is important, and the properties of the luting agent are crucial for the

Table 3. Relative number and percentage of proximal surfaces with plaque and with bleeding on probing at the 2-year examination

	Surfaces with plaque				Surfaces with bleeding on probing			
	Dual-cured Cerec surfaces ($n = 39$)		Chemically cured Cerec surfaces ($n = 42$)		Dual-cured Cerec surfaces ($n = 39$)		Chemically cured Cerec surfaces ($n = 42$)	
Surface	Relative no.	%	Relative no.	%	Relative no.	%	Relative no.	%
Mesial	7/15	46.7	10/15	66.7	1/15	6.7	2/15	13.3
Distal	17/24	70.8	16/27	59.2	7/24	31.8	7/27	25.9
Total	24/39	61.5	26/42	61.9	8/39	20.5	9/42	21.4
	Control surfaces ($n = 39$)		Control surfaces ($n = 42$)		Control surfaces ($n = 39$)		Control surfaces ($n = 42$)	
Surface	Relative no.	%	Relative no.	%	Relative no.	%	Relative no.	%
Mesial	9/15	60.0	10/15	66.6	4/15	26.7	2/15	13.3
Distal	16/24	66.7	15/27	55.5	8/24	33.3	8/27	29.6
Total	25/39	64.1	25/42	59.5	12/39	30.8	10/42	23.8

Fig. 2. Radiograph of 25 DO, 35 DO Cerec restorations cemented with Cerec Duo luting agent and 36 MO Cerec restoration cemented with Cavex Clearfil F2 luting agent and with a class-V amalgam filling.

longevity of the restorations. According to the manufacturers' information the luting agents in the present study are both classified as hybrid composite resins with medium to heavy viscosity.

However, at the moment when a restoration is seated, the viscosity of the luting agent also depends on the curing system. Both dual-cured and chemically cured composite resin luting agents begin to set when the components are mixed together; that is, their viscosity increases with time but at different rates depending on the curing system, among other things. The increasing viscosity may make it difficult to place the inlays, especially with chemically cured resins. Judging from the findings in the present study the working time seems to have been sufficient for a clinically acceptable seating of the restorations even for the chemically cured luting agent used.

In the present study shallow ditching around the inlays' margins due to wear of the luting agent was only observed on the occlusal surfaces. Van Dijken & Hörstedt (14) have also reported, in a study of Mirage inlays, that ditching around the margins of the inlays was observed more often in relation to occlusal margins than to proximal margins.

With regard to the CDA rating for the margin integrity (Table 1) and the occurrence of shallow ditches around the inlay margins (Fig. 1), there was no statistically significant difference between the two types of luting agent used in the present study. As can be seen in Fig. 1, the increase in the number of inlays with clinically detectable occlusal margins was most pronounced between base line and the 12-month re-examination and then tended to decrease. This is in accordance with the findings in a 3-year clinical study of 121 Cerec restorations by Isenberg et al. (4). They reported that clinically detectable margins increased rapidly during the 1st year but then leveled off.

With regard to surface smoothness it was shown in a previous study of 205 Cerec inlays (2) that only 26% of the inlays were rated excellent for the CDA criterion surface. The corresponding figure in a study of 205 Optec inlays (15) was 14%. The rest of the inlays in both studies were rated SRO (surface of restoration is slightly rough or pitted, can be refinished). However, at the 24-month re-examination 100% of the inlays in the present study were rated excellent for surface (Table 1). This means that it appears to be possible to polish Cerec inlays clinically to smooth, well-finished surfaces. In this context it should be observed that excessive polishing and use of abrasive pastes may also cause both postoperative sensitivity and undesirable wear of the luting agent, and the possibility cannot be excluded that the shallow ditches around the occlusal margins registered at base line (Fig. 1) have been caused by the grinding and polishing procedures.

The 24-month examination of plaque and bleeding on probing showed good results (Table 3). There was no more plaque or bleeding on probing in connection with the Cerec restorations than with the control surfaces at the 24-month examination. Therefore, it seems reasonable to assume that the materials used for the restorations do not have an injurious effect on the gingival conditions. However, the validity of this assumption can only be clarified after long-term observation, and the registrations carried out (Table 3) are intended to be followed up in a long-term study.

A clinically important property of luting agents is their radiopacity, especially since the radiographic density of many ceramics is less than that of dentin (16). One disadvantage of the chemically cured resin luting agent used in the present study is therefore its low radiopacity (Fig. 2).

Six of the 66 teeth with Cerec inlays in the present study showed slight postoperative sensitivity, but none of the patients complained of the type of sharp, clearly localized pain on loading of the inlays which has been reported in connection with posterior composite or ceramic inlays (17, 18). Besides the fact that the inlays in the present study were very carefully adjusted in occlusion and articulation, the dentin adhesive used (Gluma) may have inhibited this particular symptom, in accordance with the theory of short-circuiting the surfaces, which prevents the influence of generated electricity on the surfaces of the ceramics (19).

Conclusion

The Cerec restorations showed an almost ideal clinical performance after 2 years, and there was no significant difference between the two types of luting agent used with regard to the properties evaluated. As judged by the findings in the present intraindividual study, chemically cured luting agents may therefore serve as an alternative luting agent for ceramic inlays with mechanical properties similar to those of the ceramic used in the present study. However, further studies are necessary to predict the long-term performance of the restorative systems concerned.

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