A 5-year clinical evaluation of ceramic inlays (Cerec) cemented with a dual-cured or chemically cured resin composite luting agent

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Sixty-six class-II CAD/CAM-manufactured ceramic inlays (Cerec) were placed in 27 patients. Each patient received at least one inlay luted with a dual-cured resin composite and one inlay luted with a chemically cured resin composite. The inlays were examined 5 years after luting using the California Dental Association (CDA) criteria. Eighty-nine percent of the 66 inlays were rated 'satisfactory'. During the follow-up period replacement was required for 3 inlays because of inlay fractures (4.5%) and 1 inlay because of fracture of the tooth substance (1.5%). All those inlays were luted with the dual-cured resin composite luting agent. Of the remaining 62 inlays the CDA rating 'excellent' was given to 84% for color, 97% for surface, and 81% for anatomic form. 'Excellent' margin integrity was seen in 52% of the dual-cured resin composite luted inlays and in 61% of the chemically cured resin composite luted inlays. No statistically significant ($P > 0.05$) difference was observed between the two luting agents. □ *CAD/CAM; dental ceramics; dental materials; dental porcelain, luting*

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To date the Cerec ceramic inlays system (1, 2) is the only commercially available chair-side computer-aided system (CAD/CAM) for direct manufacture of ceramic inlays. This system was introduced in the late 1990s, and the introduction of the CAD/CAM technique into dentistry has made it possible to make ceramic restorations in one sitting. This technique has also made it possible to use prefabricated ceramics (1, 2), which are produced under more controlled conditions than those used in ceramic restorations produced manually in dental laboratories.

Short-time evaluations of Cerec ceramic restorations have shown clinically acceptable results (e.g. 3–6). The Cerec restorations evaluated in these clinical studies were mostly luted with dual-cured resin composite luting agents. The polymerization of dual-cured resin composite luting agents depends, among other things, on exposure time and the intensity of the light source (7–13), and it has been reported (8–10) that dual-cured resin composite luting agents are not sufficiently polymerized under thick and/or opaque ceramic or resin composite restorations. The shade of the restoration can also influence the polymerization (9). It is therefore questionable whether there is sufficient hardening of the dual-cured resin luting agents in those parts of a tooth reached by insufficient light intensity. It was thus interesting to study whether chemically cured resin composites could serve as alternative luting agents when Cerec ceramic inlays were placed. To this end an intraindividual comparison of Cerec class-II inlays luted with either a chemically cured or a dual-cured resin composite was undertaken. The 2-year results of this study have been presented earlier (14).

Since fatigue and failure risk may increase with time for dental restorations, it was also of interest to evaluate these restorations after 5 years of clinical service. The aim of the present work therefore was to evaluate the Cerec ceramic class-II restorations, cemented using either a dual-cured or a two-component chemically cured resin composite, 5 years after luting.

Materials and methods

The initial material consisted of 66 Cerec ceramic class-II inlays (Vita Mark II, Vita Zahnfabrik, Bad Säckingen, Germany). The inlays were made by three dentists in accordance with the manufacturer's instructions (1) using the Cerec CAD/CAM system (Cerec System, software C.O.S. 2.0, Siemens AG, Bensheim, Germany). The inlays were placed on molars or premolars in 27 patients (17 female and 10 male) who ranged in age from 15 to 65 years (mean, 37 years) and regularly visited Public Dental Health Service Clinics or Umeå University Dental School. At the initial examination routine anamnestic records and any symptoms from the temporomandibular joint (TMJ), masticatory muscles, and oral mucosa were monitored.

An impression was taken of each preparation with an A-silicone (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). These stone die models were intended to make it possible to analyze a potential influence of the preparation design in case of a fracture of an inlay. Fifty-four of the inlays were made directly, and 12 were made indirectly on die stone models (Kerr Vel-Mix Stone ISO Type IV) after impression using an A-silicone (President).

On a randomized basis half the inlays in each patient were luted using a two-component dual-cured hybrid resin composite luting agent (Vita Cerec Duo Cement, batch 9110–983, Coltène) and the rest using a chemically cured two-component hybrid resin composite (Cavex Clearfil F2, batch 910415, Cavex Holland BV, RW Haarlem, The Netherlands). The Gluma primer of the original four-step Gluma system (Gluma, Bayer, Leverkusen, Germany) was placed on the dentin and subsequently air-sprayed. The enamel bonding agents used were those recommended by the manufacturers of the resins (Coltène Duo Bond Kit, batch 9205–510, Coltène, and Cavex Clearfil F2, batch 911001, Cavex, respectively).

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 indications for the treatment, preparation design, pretreatment of the cavities, luting procedures, contouring, and polishing procedures have been presented earlier (14).

Evaluation

The inlays were examined in accordance with the quality evaluation system of the California Dental Association (CDA) (15). Each inlay was evaluated by two calibrated evaluators working in pairs but independently. Margin integrity, anatomic form, surface, and color were evaluated. Whenever the ratings differed the pair of examiners resolved their disagreement by joint examination. In addition, the patients were questioned about postoperative sensitivity in accordance with the system used by Borgmeijer et al. (16). The position of the proximal cervical inlay margins, in accordance with Silness (17), was also registered.

Statistical analysis

The values obtained for the CDA scores for each type of luting agent were analyzed statistically using Fisher's exact test (18) for difference of proportions at a significant level of 0.05.

Results

At the 5-year recall all 27 patients were reexamined. There were no changes influencing the durability of the inlays observed with respect to anamneses, symptoms from

Table 1. Percentage and number of Cerec inlays that did not receive a rating of 'excellent' according to the California Dental Association ratings.* At baseline $n = 33$ for each group. At the 5-year reexamination, owing to replacement of inlays due to fractures, $n = 29$ for the inlays luted using the dual-cured luting agent, and $n = 33$ for those luted using the chemically cured luting agent with regard to anatomic form, color, and surface. For margin integrity $n = 33$ for both groups since the cumulative frequency is given for margin integrity

	Baseline				5-year			
	Dual-cured		Chemically cured		Dual-cured		Chemically cured	
	%	*n*	%	*n*	%	*n*	%	*n*
Margin integrity								
SDIS					21	7	24	8
SCR	3	1			12	4	9	3
VTF					3	1		
VFR					12	4	3	1
TMD							3	1
Anatomic form								
SCO	6	2	3	1	7	2	3	1
SPX	3	1	3	1				
SUCO			6	2			6	2
SOCO	6	2	6	2	3	1	3	1
SMR					3	1	9	3
SOH							3	1
Color								
SMM	9	3	9	3	17	5	15	5
Surface								
SRO					3	1	3	1

*SDIS = discoloration on margin between the restoration and tooth structure; SCR = visible evidence of ditching along the margin not extending to the dentinoenamel junction; VTF = tooth structure fractured; VFR = fracture of the restoration; TMD = dentin or base exposed along the margin; SCO = contact slightly open (may be self-correcting); SPX = interproximal cervical area slightly under-contoured; SUCO = restoration slightly under-contoured; SOCO = restoration slightly over-contoured, but excess material could be removed; SMR = marginal ridges slightly under-contoured; SOH = occlusal height reduced locally (not in toto); SMM = slight mismatch between restoration and tooth structure within normal range of tooth color; SRO = surface of restoration slightly rough and pitted, can be polished.

the TMJ, or masticatory muscles compared with the findings at the initial examination.

Eighty-nine percent of the 66 inlays were rated 'satisfactory'. The number and percentage of the inlays that did not receive an 'excellent' CDA rating at baseline and at the 5-year reexamination are shown in Table 1. Seven inlays, 5 in the dual-cured group and 2 in the chemically cured group, were rated 'not satisfactory'. The distribution of restored tooth, type of restoration, and luting agent used for the inlays rated 'not satisfactory' are presented in Table 2. All 3 fractured inlays that had to be replaced were placed in molars and cemented with the dual-cured luting agent. The distribution of the luting agents of all the inlays placed on molars was 7 inlays cemented with the dual-cured luting agent and 6 with the chemically cured. Another inlay (premolar) luted with the dual-cured luting agent required replacement because of tooth fracture. In Fig. 1 an isthmus fracture in a maxillary left first molar 5 years after luting is shown. Of the remaining 62 inlays, the CDA rating 'excellent' was given for color to 84%, 97% for surface, and 81% for anatomic form. 'Excellent' margin integrity was seen in 52% of the 33 dual-cured resin composite luted inlays and in 61% of the 33 chemically cured resin composite luted inlays. The values for margin integrity are given as cumulative frequencies. No obvious reasons for the fracture of the inlays could be seen in the cavity design. Two of the patients with inlays that had to be replaced because of fractures had no idea when or how the fractures had appeared. Two inlays were rated VFR (fracture of the restoration) because of a minor fracture at the margin, or the marginal ridge, and still functioned after adjustment. Initial caries was observed in connection with 1 proximal margin at the 5-year reexamination. None of the patients reported any postoperative symptoms in relation to the Cerec inlays. Regarding the margin level, most of the cervical proximal margins were placed subgingivally, and, compared with baseline, there were no substantial changes.

No statistically significant ($P > 0.05$) difference was observed between the two luting agents.

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

Discussion

In combination with the so-called adhesive luting techniques, the improved properties of dental ceramics have extended the indication for ceramic restorations. This has resulted in, among other things, an increased use of ceramic inlays for restoring class-I and class-II cavities. Since the properties of the luting agent are crucial to the longevity of cemented dental restorations, and some doubt about the setting of dual-cured luting agents has previously been reported (7–13), it was of particular interest to study whether a chemically cured resin composite could serve as a satisfactory luting agent for ceramic inlays. The chemically cured resin composite used in the present intraindividual study was, however, primarily intended as an anterior restorative material. This resin composite was chosen since no suitable chemically cured resin composite luting agent intended for luting ceramic inlays was commercially available when the present study began. This resin composite had previously also shown promising results both when used for luting purposes, for example in a clinical study of resin bonded bridges (19), and in an in vitro study (20). Statistically, no significant ($P > 0.05$) difference was observed between the two luting agents in the present study. However, a clinical significance can be seen since all the inlays that required replacement were luted with the dual-cured resin composite. This has to be followed up in a long-term study since a longer observation period is needed to assess the effect of fatigue.

During the first year after luting of the Cerec inlays, it was shown (14) that the occurrence of shallow ditching around the occlusal margins of the inlays increased markedly, probably owing to wear of the luting agents. However, the frequency of inlays rated SCR (visible evidence of ditching along the margin not extending to the dentinoenamel junction) had not increased markedly at

Table 2. Distribution of the restorations ranked 'not satisfactory' according to the quality evaluation criteria of the California Dental Association. The number of years refers to the time period between luting and when the deficiencies were registered

	Replaced inlays owing to fractures or defect margin integrity				Inlays with deficiencies, not replaced			
	Dual-cured		Chemically cured		Dual-cured		Chemically cured	
Fracture/exposure	Tooth	Years	Tooth	Years	Tooth	Years	Tooth	Years
Fractured inlays	47 MOD	3						
	46 MOD	4						
	26 MO	5						
Chip fracture at the margin							37 MO	2
Fracture of the marginal ridge					14 DO	3		
Tooth fracture	45 MOD	2						
Dentin or base exposed along the margin			46 MO	5				

Fig. 1. Fracture that occurred in a maxillary left second molar 5 years after luting.

the 5-year reexamination compared with baseline. In a 3-year follow-up study of Optec inlays (19) luted using dual-cured resin composites, it was shown that the frequency of inlays rated SCR had increased by almost 50% between the 1-year examination and the 3-year reexamination. Discoloration (SDIS) of the margin between the Optec restorations and the tooth structure had also increased markedly (21). In the present study discoloration had increased after 5 years from 0% at baseline to 21% for the inlays luted with the dual-cured luting agent and 24% for the inlays luted using the chemically cured luting agent. Regarding surface the Cerec inlays in the present study achieved almost similar ratings at baseline and at the 5-year reexamination. In a study of 205 Cerec inlays carried out by general practitioners (4), 78% were rated SRO (surface of restoration is slightly rough or pitted, can be polished) compared with 3% of the Cerec inlays in the present study. Thus, the Cerec inlays in the present study had largely maintained the smooth, well-finished surface obtained at baseline. One of the reasons for the difference between the study of the 205 Cerec inlays (4) and the present study with respect to the surface finish can be that, in the former study, two types of ceramic blocks were used, the Vita Cerec MK I and the Vita Cerec MK II. The Vita Cerec MK I, said to have a coarser structure than the Vita Cerec MK II, should have been used for most of the inlays in that study (4). Among the Optec inlays (21), those with a slightly rough or pitted surface had increased from 86% at the 1-year examination to 96% at the 3-year reexamination. The slight differences observed in the current study between the CDA ratings at baseline and at the 5-year reexamination (Table 1) with regard to the ratings SPX and SUCO were probably caused by differences in the evaluation scores given at the different evaluations.

An overview of failure-rates reported in some studies dealing with ceramic inlays and onlays is presented in Table 3. In the present 5-year study, 6.1% of the 66 Cerec inlays required replacement because of inlay or tooth fractures. The failure rates for Cerec inlays/onlays presented in Table 3 vary between 2.4% and 10.2%. Higher failure rates, 12% and 26%, respectively, were reported 6 years after luting in an intraindividual study of 115 Mirage inlays luted with either a dual-cured resin composite or a GPA cement (29). In this study total loss of 5 inlays and 11 fractured inlays luted with the GPA cement were registered, whereas in a study of 35 Cerec inlays luted with either 3 different resin composites or a GPA cement, only 1 inlay had fractured after 3 years (30). In the latter study the number of inlays luted with the different luting agents was low, making it difficult to interpret the effect of the type of ceramic and luting agents used on the failures rates as shown for the fired ceramic inlays.

As can be seen in Table 3, both the failure rates and the follow-up periods vary considerably between the different studies. The distribution of molars and premolars restored also varies. In addition, in some studies patients with parafunctional habits, such as tooth grinding and clenching, or patients with 'poor oral hygiene' have been excluded (e.g. 22, 27, 28). Factors that have to be taken into consideration when failure rates reported are com-

Table 3. Reported failure-rates of ceramic inlays/onlays

Author(s)	No. of patients	No. of restorations	Time in clinical service	Restoration	Failure-rate, replaced or repaired (%)
Sjögren et al. (4)	72	205	12–24 months	Cerec*	2.4
Heymann et al. (6)	28	50	4 years	Cerec*	0
Molin & Karlsson (21)	47	145	3 years	Optec*	14
Berg & Dérand (22)	46	115	5 years	Cerec*	2.6
Pallesen (23)	16	32	6 years	Cerec*	9
Walther & Reiss (24)	299	1011	40–80 months	Cerec*	3.9
Hofmann et al. (25)	59	59	5 years	Cerec*	10.2
Tidehag & Gunne (26)	18	62	2 years	Empress*	1.7
Fradeani et al. (27)	29	125	7–56 months	Empress*	3.3
Studer et al. (28)	36	130	23.4 ± 6.1 months	Empress*	2.3
van Dijken et al. (29)	50	59	6 years	Mirage*	12
		59		Mirage†	26
Zuellig & Bryant (30)	18	36	3 years	Cerec*/†	2.8

* Luted with resin composite.
† Luted with GPA cement.

pared with each other, especially since the risk of fatigue and failure increases with time.

Summary

The results can be summarized as follows:

1) On the basis of the criteria of the CDA quality evaluation system, 89% of the 66 Cerec inlays were rated 'satisfactory' 5 years after luting.

2) Four inlays were replaced because of inlay or tooth fractures during the follow-up period. Two inlays with minor defects were easily adjusted and are still functioning. All restorations that required replacement were cemented with the dual-cured luting agent. All fractured inlays that had to be replaced were placed in molars.

3) No statistically significant ($P > 0.05$) difference was observed between the two luting agents.

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