A 10-year Prospective Evaluation of CAD/CAM–Manufactured (Cerec) Ceramic Inlays Cemented with a Chemically Cured or Dual-Cured Resin Composite

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Purpose: The present follow-up study was carried out to evaluate the performance of Class II Cerec inlays after 10 years of clinical service. ***Materials and Methods:*** Sixty-six Class II CAD/CAM ceramic inlays 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. At the 10-year recall, 25 (93%) patients with 61 (92%) inlays were available for evaluation using a slight modification of the USPHS criteria. ***Results:*** Fifty-four (89%) of the 61 inlays reevaluated still functioned well at the 10-year recall. During the follow-up period, seven (11%) of the inlays required replacement because of: four inlay fractures, one cusp fracture, endodontic problems in one case, and postoperative symptoms in one case. All the replaced inlays had been luted with the dual-cured resin composite. The fractured inlays were all placed in molars. The estimated survival rate after 10 years was 89%, 77% for the dual-cured resin composite–luted inlays and 100% for the chemically cured resin composite–luted ones. The difference was statistically significant. ***Conclusion:*** Patient satisfaction with and acceptance of the Cerec inlays were high, and the performance after 10 years of clinical service was acceptable, especially regarding the inlays luted with the chemically cured resin composite. The properties of the luting agents seem to affect the longevity of the type of ceramic inlays evaluated. *Int J Prosthodont 2004;17:241–246.*

The computer-aided design/manufacturing (CAD/CAM) technique became available in dentistry in the late 1980s.[1,2] The direct chairside Cerec system (Siemens), introduced in 1988, allows ceramic inlays and onlays to be made in one sitting.[3] The system uses prefabricated ceramic blocks that are intended to be adhesively luted with resin composite cements,[1] and those usually used are dual cured. This technique has been evaluated in a number of clinical studies.[4–9] It has, however, been shown in vitro that curing of light- and dual-cured resin composite cements is dependent on exposure time, and the intensity of the light source used and the thickness and shade of the ceramic influence the degree of polymerization of these composites.[10–16] A lower conversion rate in resin composite luting agents may affect the clinical durability of ceramic inlays.

Therefore, an intraindividual study of Cerec ceramic Class II inlays luted with either a chemically cured or a dual-cured resin composite was initiated. The 2- and 5-year results of this study have been presented.[17,18] Since the risk of failure in dental restorations increases with time, the Cerec Class II inlays were reevaluated after 10 years of clinical service. Thus, the aim of the present work was to evaluate Cerec ceramic Class II inlays, cemented with either a dual-cured or a chemically cured resin composite, 10 years after luting. The null hypothesis was that there would be no difference in durability between the Cerec inlays luted with the two resin composites.

Materials and Methods

The initial material consisted of 66 Cerec ceramic Class II inlays (Vita Mark II). The inlays were made by three

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Table 1 Criteria for Direct Clinical Evaluation

Category/score	Criteria
Anatomic form	
0 (acceptable)	Restoration is contiguous with tooth anatomy
1 (acceptable)	Slightly over- or undercontoured restoration; marginal ridges slightly undercontoured; contact slightly open (may be self-correcting); occlusal height reduced locally
2 (unacceptable)	Restoration is undercontoured, dentin or base exposed; contact is faulty, not self-correcting; occlusal height reduced; occlusion affected
3 (unacceptable)	Restoration is partially or completely missing; fracture of tooth structure; traumatic occlusion; restoration causes pain in tooth or adjacent tissue
Marginal adaptation	
0 (acceptable)	Restoration is contiguous with existing anatomic form; explorer does not catch
1 (acceptable)	Explorer catches; no crevice into which explorer will penetrate is visible
2 (acceptable)	Crevice at margin, enamel exposed
3 (unacceptable)	Obvious crevice at margin, dentin or base exposed
4 (unacceptable)	Restoration mobile, fractured, or missing
Color match	
0 (acceptable)	Very good color match
1 (acceptable)	Good color match
2 (acceptable)	Slight mismatch in color, shade, or translucency
3 (unacceptable)	Obvious mismatch, outside normal range
4 (unacceptable)	Gross mismatch
Marginal discoloration	
0 (acceptable)	No discoloration evident
1 (acceptable)	Slight staining, can be polished away
2 (acceptable)	Obvious staining, cannot be polished away
3 (unacceptable)	Gross staining
Surface roughness	
0 (acceptable)	Smooth surface
1 (acceptable)	Slightly rough or pitted
2 (acceptable)	Rough, cannot be refinished
3 (unacceptable)	Surface deeply pitted, irregular grooves
Caries	
0 (acceptable)	No evidence of caries contiguous with restoration margin
1 (acceptable)	Evidence of superficial caries; no operative treatment necessary
2 (unacceptable)	Caries evident contiguous with restoration margin; operative treatment indicated

clinicians in accordance with the manufacturer's instructions using the Cerec CAD/CAM system (Cerec system software COS 2.0, Siemens).[1] The inlays were placed on molars or premolars in 27 patients (17 women and 10 men) who regularly visited Public Dental Health Service Clinics or Umeå University Dental School, Sweden.

At the initial examination, routine history and any symptoms from the temporomandibular joint (TMJ), masticatory muscles, and oral mucosa were recorded. Fifty-four of the inlays were made directly in the mouth, and 12 were made indirectly on die stone models (Kerr Vel-Mix Stone ISO type IV, Kerr) after an impression was made using an A-silicone (President, Coltène). In addition, to allow analysis of any potential influence the preparation design might have on the fracture of an inlay, an impression was taken of each preparation with an A-silicone (President) or an irreversible hydrocolloid (Algi-X, Svedia Dental), and stone die models were made (Kerr Vel-Mix Stone ISO type IV).

On a randomized basis, 33 of the inlays were luted using a dual-cured hybrid resin composite luting agent (Vita Cerec Duo Cement, batch No. 9110-983, Coltène), and 33 were luted using a chemically cured hybrid resin composite (Cavex Clearfil F2, batch No. 910415, Cavex). Each patient received at least one inlay luted with the dual-cured resin composite and one inlay luted with the chemically cured resin composite. The original four-step Gluma system (Bayer) was used as a primer. The primer was placed on the dentin and subsequently air dried. Enamel bonding agents recommended by the manufacturers of the resins (Coltène Duo Bond Kit, batch No. 9205-510; and Cavex Clearfil F2, batch No. 911001) were used.

Fifty-three premolars and thirteen molars, including four second molars, were restored. Fifteen inlays were three-surface restorations on premolars, and two were three-surface restorations on molars. Thirty-eight inlays were two-surface restorations on premolars, and eleven were two-surface restorations on molars. Twenty-five of the two-surface restorations were luted

with the dual-cured luting agent, and twenty-four were luted with the chemically cured agent. Corresponding figures for the three-surface restorations were eight and nine, respectively.

The indications for the treatment, the preparation design, pretreatment of the cavities, luting procedures, and contouring and polishing procedures have been presented.[17] The authors estimated the caries risk for each patient by means of clinical and sociodemographic information routinely available from annual clinical examinations, eg, incipient caries lesions and former caries histories.[19,20]

Evaluation and Statistical Analysis

Three evaluators (the authors), who were mutually calibrated, performed the 10-year registrations. A slight modification of the United States Public Health Service (USPHS) criteria was used to evaluate the inlays (Table 1). In addition, each patient was interviewed regarding satisfaction with the restorations and the occurrence of any postoperative inconvenience.

The Kaplan-Meier statistic[21] was used to calculate the survival rate of the inlays. Durability of the two luting agents was compared and tested using the McNemar test.[22] The null hypothesis was rejected at the 5% level.

Results

At the 10-year recall, all but 2 of the initial 27 patients were reexamined (16 women and 9 men). The mean and median ages of the reexamined patients were 48 years and 50 years, respectively (range 26 to 73 years). No substantial changes were observed with respect to history, symptoms from the TMJ, or masticatory muscles compared to the initial examination. All patients were satisfied with their inlays. The 2 patients who did not attend the 10-year recall each had two Cerec Class II inlays. They reported that their inlays still functioned well more than10 years after cementation. To achieve an abutment for a fixed partial denture, a third patient had one inlay, luted with the dual-cured resin composite cement, replaced with a metal-ceramic crown 7 years after cementation. No deficiency in connection with this inlay was seen at the time of replacement.

Thus, of the 66 inlays originally placed in 27 patients, 25 (93%) patients with 61 (92%) inlays were available for a follow-up evaluation after 10 years. The mean and median ages of the reevaluated inlays were both 10 years (range 8.2 to 11.2). Frequencies of the USPHS scores obtained are presented in Table 2. Fifty-four (89%) of the 61 inlays still functioned well at the 10-year recall. Of those 54 inlays, 23 were luted with the dual-cured resin composite, and 31 were luted with the chemically cured one.

Seven inlays (11%) placed in seven different patients were replaced because of fractures, endodontic problems, or postoperative symptoms (Table 3). All

Table 2 Distribution of Modified USPHS Scores (%) After 10 Years for Cerec Class II Inlays Luted with the Two Resin Composites

Category/score	Dual-cured resin composite	Chemically cured resin composite
Anatomic form*		
0 (acceptable)	73	81
1 (acceptable)	15	16
2 (unacceptable)	0	6
3 (unacceptable)	12	0
Marginal adaptation*		
0 (acceptable)	22	6
1 (acceptable)	52	68
2 (acceptable)	11	26
3 (unacceptable)	0	0
4 (unacceptable)	15	0
Color match		
0 (acceptable)	5	7
1 (acceptable)	52	61
2 (acceptable)	43	32
3 (unacceptable)	0	0
4 (unacceptable)	0	0
Marginal discoloration		
0 (acceptable)	78	58
1 (acceptable)	13	19
2 (acceptable)	9	23
3 (unacceptable)	0	0
Surface roughness		
0 (acceptable)	35	26
1 (acceptable)	56	64
2 (acceptable)	9	10
3 (unacceptable)	0	0

*Values are given as cumulative frequencies.

Table 3 Replaced Cerec Class II Inlays, Reasons for Failure,* and Time in Function

Tooth/type	Reason for failure	Time in function (y)
Mandibular right second premolar/mesio-occlusodistal	Tooth fracture	2
Mandibular right second molar/mesio-occlusodistal	Inlay fracture	3
Mandibular right first molar/mesio-occlusodistal	Inlay fracture	4
Maxillary left first molar/mesio-occlusal	Inlay fracture	5
Mandibular left first molar/mesio-occlusal	Inlay fracture	7
Mandibular left second premolar/disto-occlusal	Endodontic problems	7
Mandibular left second premolar/disto-occlusal	Postoperative symptoms	10

*All failed inlays had been luted with dual-cured resin composite.

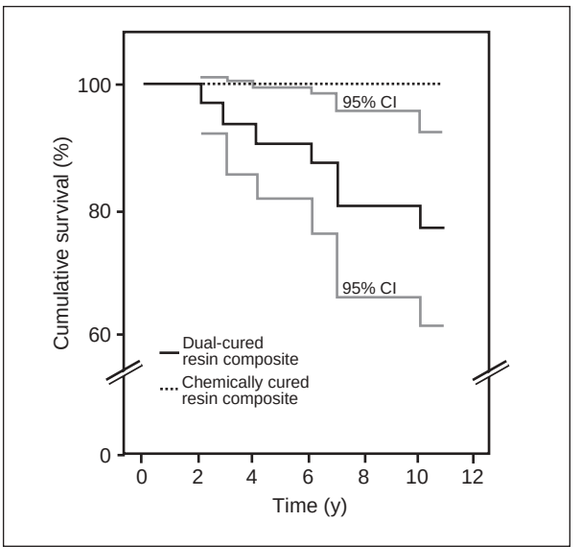

Fig 1 Kaplan-Meier survival analysis of the 61 inlays evaluated as a function of time and luting agent used. *CI* = confidence interval.

four fractured inlays replaced were in molars and luted with the dual-cured resin composite cement. No obvious reasons for the fracture of the inlays could be seen in the cavity design. The three inlays that were replaced because of tooth fracture, endodontic problems, or postoperative symptoms were all in premolars luted with the dual-cured resin composite cement. One patient reported intermittent postoperative symptoms related to the region of one inlay cemented with the dual-cured luting agent. The symptoms were not related to occlusal stress or temperature changes. After replacement of the Cerec inlay with a direct resin composite restoration at the 10-year recall, the symptoms remained in the region of the tooth after 4 months. In addition, one inlay luted with the dual-cured resin cement and one luted with the chemically cured resin cement exhibited minor fracture at the margin, or at the marginal ridge that had been previously adjusted, and the dentin was exposed in connection with one inlay cemented with the dual-cured luting agent 5 years after luting. Those inlays still functioned well at the 10-year recall.

No evidence of caries was seen in connection with the inlays. Twenty-four percent of the patients were assessed as being a caries risk. Most of the cervical proximal margins were placed subgingivally; compared to baseline, there were no substantial changes regarding the margin level. According to the Kaplan-Meier method and the failure criterion, the estimated survival rate after 10 years was 89%, 77% for the dual-cured resin composite–luted inlays and 100% for the chemically cured resin composite–luted inlays (Fig 1). The difference was statistically significant ($P < .05$). The interexaminer agreement for the USPHS quality rating exceeded 85%.

Discussion

Between the 5-year recall and the present examination, three inlays failed because of inlay fracture, endodontic problems, or postoperative symptoms. In total, seven inlays were replaced during the 10-year follow-up period, resulting in a 1.1% annual failure rate.

There are very few studies dealing with ceramic inlays that have been in clinical service for 10 years or more, and therefore few comparisons can be made. In an 8-year follow-up of Cerec inlays, 6% were replaced because of fracture of the inlays.[7] A 10-year follow-up of 187 Cerec inlays reported an 8% failure rate; 3% of the 187 inlays were replaced, and 2% were repaired with resin composite because of ceramic fractures.[9] The annual failure rate obtained in the present study is slightly higher than those reported for Cerec inlays in the previous studies,[7,9] but similar or lower compared with the values reported in some other, shorter follow-up studies of Cerec, laboratory-made ceramic inlays, resin composite, and amalgam restorations.[23–25] The annual failure rate in a 6-year follow-up study of fired ceramic inlays (Mirage, Chameleon Dental) was 2% for the inlays luted with a dual-cured resin composite and 4% for those luted with a GPA cement.[23] For glass-ceramic inlays (Dicor, Dentsply), amalgam restorations, and direct resin composite inlays, the annual fracture rates were 1.7%, 1.7%, and 1.0%, respectively.[24,25] The estimated survival rates after 6 years reported in the study of Dicor ceramic inlays and amalgam restorations were 76% and 87%, respectively.[24] No statistical differences were found between the longevity of the Dicor and amalgam restorations.[24] In the present study, all fractured inlays were placed in molars with the dual-cured resin composite, and all of the replaced inlays were luted with the dual-cured resin composite. The inlays luted with the chemically cured resin composite exhibited 100% success, except for a minor fracture at the margin of one inlay after 3 years that was easily adjusted and one inlay in which the dentin was exposed after 5 years. Both those inlays were still in function at the 10-year recall.

Regarding surface roughness, 3% of the inlays were rated to have a "slightly rough and pitted surface" at the 5-year recall[18]; that figure was 60% at the 10-year recall. Mismatch in color increased from 16% at the 5-year recall[18] to 38% at the 10-year recall. Relative

changes in color and surface of Cerec inlays were also reported in other 5- and 10-year follow-ups.[6,9] The suggested reasons for the changes are mechanical stress, chemical degradation, and change in the color and translucence of the natural teeth.[6,9]

The occurrence of ditching along the occlusal margin increased from 12% for the dual-cured resin composite–luted inlays and 9% for the chemically cured resin composite–luted inlays at the 5-year recall[18] to 52% and 68%, respectively, at the 10-year recall. Clinically detectable ditching was observed only along the occlusal margins. No caries was observed contiguous to the inlays, and no additional negative effects of the ditched margins were seen on the clinical durability of the inlays. The fact that the ditching along the occlusal margins increases with time has been shown in previous long-term studies of Cerec and laboratory-made ceramic inlays.[6,9,23,26–29] In a 10-year follow-up of Cerec inlays luted with a dual-cured resin composite,[9] ditching increased from 12% after placement to 74% after 10 years; in a 5-year follow-up of ceramic inlays, ditching at the margin was a frequent finding (70%).[6]

In the present study, the chemically cured resin composite–luted inlays showed better durability. One conceivable explanation for why all failed inlays were luted with the dual-cured resin composite is that the polymerization of the dual-cured resin composite used was insufficient in certain areas. The self-curing of dual-cured resin composite can be insufficient to achieve adequate hardening when light is attenuated through the inlays and/or tooth substance, depending on the thickness and shade of the ceramic.[10–16,30,31] Consequently, the luting agent cannot withstand the stresses and strains that can arise in posterior regions, and the inlays fracture more easily on intermittent loading. In vitro studies of dual-cured resin composite cements show that the degree of hardening is significantly reduced when only the self-curing part is used, and that there is variation among the cements evaluated.[30,31] It was suggested that the composition of the cements is the reason for this variation. A sufficient amount of self-curing chemicals incorporated in the material allows adequate polymerization in areas that are inaccessible to the curing light. Insufficient self-curing elements/compounds results in inadequate hardening of the resin composite cement, and it has been suggested that the efficiency of the self-curing components should be optimized.[30,31] However, a 5-year follow-up study of posterior partial and complete ceramic restorations (IPS Empress, Ivoclar Vivadent) luted with a dual-cured or chemically cured resin composite showed no significant difference in failure rates between the two luting agents.[32] A high-intensity lamp was used in that study, and it was assumed that this resulted in optimally converted resin composite beneath the ceramic restorations.[32]

A low annual failure rate (1.1%) after 10 years of clinical service was observed. Patient satisfaction with and acceptance of the Cerec inlays were high. Inlays luted with the chemically cured resin composite showed a greater durability than the dual-cured resin composite–luted inlays. The clinical performance of the Cerec inlays in the present study was regarded as acceptable 10 years after cementation, especially those luted with the chemically cured resin composite.

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Literature Abstract

Biomechanics of human temporomandibular joint during chewing.

Experimental data on the loading of the human TMJ during chewing are scarce. Previous studies demonstrated that coincidence of the opening and closing chewing strokes of the condyles probably indicates compression in the joint during chewing. Using this indication, the authors studied TMJ loading during chewing and chopping (mainly vertical chewing strokes) of a latex-packed food bolus on the left and right sides of the mouth. Mandibular movements of 10 healthy subjects (five women and five men, 21 to 32 years old, free of TMD) were recorded by the "6 degrees of freedom" jaw-movement recording system, OKAS-3D. Each subject was instructed to chew or chop a test food bolus of 1 cm^3. Distances traveled by the condylar kinematic centers were normalized with respect to the distance traveled during maximum opening. An author experienced in the analysis of condylar movements judged coincidence of the opening and closing condylar movement traces without knowing their origin. When subjects chewed, the ipsilateral condyles traveled shorter distances than the contralateral condyles. During chewing and chopping, all contralateral condyles showed a coincident movement pattern, while a significantly smaller number of ipsilateral condyles did. These results suggest that ipsilateral joints were less heavily loaded during chewing and chopping than were the contralateral joints.

Naeije M, Hofman N. *J Dent Res* 2003;82:528–531. **References:** 15. **Reprints:** Dr M. Naeije, Department of Oral Function, Section of Oral Kinesiology, Academic Centre for Dentistry Amsterdam, Louwesweg 1, 1066 Amsterdam, The Netherlands. e-mail: m.naeije@acta.nl—*Tee-Khin Neo, Singapore*