

A 3-year clinical follow-up study of a ceramic (Optec) inlay system

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To evaluate the clinical quality of ceramic (Optec) inlays, the inlay production of 10 dentists, served by 3 dental laboratories, was examined independently by 2 calibrated examiners. Of the 57 patients with 205 inlays participating in the first examination, 47 patients with 145 remaining inlays participated in the 3-year follow-up reexamination. For 14 of the participants in the reexamination, altogether 21 inlays had fractured. The mean time in service before fracture was 26.4 months (range, 12-53 months). The inlays were rated using the California Dental Association (CDA) quality evaluation system. This examination showed that the mismatch of color had increased from the first examination to the reexamination and registered slightly roughened surfaces. As to anatomic form, a reduced number of inlays did not receive an excellent CDA rating at the reexamination. Visible evidence of ditching along the margin had increased by almost 50%, and an apparent discoloration of the margin between the restoration and the tooth structure was seen in 73% of the reexamined inlays, compared with 7% at the first examination. □ *Ceramic inlays; clinical examination; dental materials; porcelain*

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Patients' increasing demand for tooth-colored, non-metallic restorations has resulted in the frequent use of ceramic materials in restorative dentistry today. Ceramic materials are well known to be biocompatible, but owing to their brittle nature, they have not gained full acceptance for use in all cases. However, new ceramic materials with more favorable mechanical properties may have the potential to function more effectively as inlays, and the inclusion criteria for their use have therefore been extended. Besides the mechanical properties, much concern has been dedicated to marginal fit. In vitro studies have reported that the marginal fit of ceramic inlays is inferior to that of gold inlays (1, 2). Furthermore, the marginal fit has been reported to differ significantly among different ceramic materials (2-5). However, the adhesive luting technique, using a composite resin luting agent for bonding, will compensate for the marginal discrepancy and increase the ability of the porcelain inlay to withstand loading (6-9). Several studies, dealing with the clinical quality of different ceramic inlay materials over time, have presented acceptable results (10-15). However, the observation time in most of the studies has been short, not exceeding 1 year. Thus, the aim of the present study was to present the 3-year results of a so-called high-strength porcelain system (Optec) used for the inlay procedure. The 1-year results have been presented in a previous study (12).

Materials and methods

By questioning three dental laboratories in Sweden about their Optec inlay production, 10 dentists—7

private and 2 general practitioners and 1 faculty staff member—were located. On request they all agreed to having their patients with Optec inlays participate in a clinical evaluation.

The initial material consisted of 57 patients, 39 women and 18 men, treated with altogether 205 Optec inlays. Complications that had appeared between the initial examination and the reexamination were reported by each dentist, as was the subjective impression of each patient. The margin index, in accordance with Silness (16), and the plaque and bleeding indices, in accordance with Lenox & Kopczyk (17), were monitored. For comparison, the periodontal variables were recorded on both the tooth restored with an inlay and the available homologous surfaces not treated with inlays. The restorative status of the homologous teeth was also recorded.

The two authors examined all the restorations independently of each other, in accordance with a slightly modified form of the Californian Dental Association's (CDA) system for quality assessment of dental care (18). The clinical examination and evaluation was performed by the authors after a careful calibration procedure in accordance with the CDA guidelines. After the evaluation of each patient, the examiners discussed dissimilar ratings, to reach consensus. The CDA criteria focused on Surface and Color, Anatomic Form, and Margin Integrity. Each restoration was given a rating representing one of two main categories: Satisfactory with the subratings Romeo (R), indicating range of excellence, and Sierra (S), indicating the range of acceptability. For Not Acceptable, Tango (T) indicates correction needed for prevention of future damage, and Victor (V) indicates

Table 1. Number, mean age, and range of Optec inlays related to treating dentist and dental laboratory

Treating dentist	Dental laboratory	No. of inlays after first exam. (n)	Present no. of inlays (n)	Mean age (months)	Range (months)	No. of fractured inlays (n)
A	I	14	9	46.1	44-52	5
B	I	4	4	51.5	48-55	0
C	II	36	35	47.2	38-54	0
D	I	8	6	39.5	39-40	0
E	II	20	12	45.1	39-57	8
F	I	11	8	49.3	40-68	2
G	II	9	7	40.1	37-51	0
H	I	17	8	39.8	37-45	2
I	III	51	35	41.5	37-46	2
J	III	35	21	41.5	38-48	2
Total		205	145	44.2	37-68	21

that damage is presently occurring. As to Color, the subrating excellent (R) was modified in the form of absolutely perfect (R0) and small mismatch in color (R1).

Results

Of the initial 57 patients, 47 patients, 31 women and 16 men, participated in the 3-year follow-up examination. Their mean age was 45 years (range, 18-75 years). Of the 10 patients that did not participate in the study, 2 could not be located, and 8 patients declined examination. The initial and present number of inlays, the mean age, the range of the present Optec inlays, and the number of fractured inlays related to treating dentist and dental laboratory is presented in Table 1. Of the examined 145 inlays (71% of the initial number of inlays) at the reexamination, 81 were placed in the molar and 64 in the premolar region. Twelve inlays were of the class-I and 135 inlays of the class-II type of restoration. Of the 47 patients participating in the reexamination, 14 patients (30%) had fractured inlays that were replaced by either new Optec inlays or by composite or gold inlays. Of the 21 fractured inlays (13%), 12 had been seated in molars and 9 in premolars. All fractured inlays were of the class-II type of restoration. The date for the fractures could be registered for 18 inlays, and the mean time to fracture was 26.4 months (range, 12-53 months). In three cases the fractures had been registered at the yearly examination, and the patient had no idea about how and when the fracture had appeared. Two of the teeth with fractured inlays had not been treated with a dentin bonding agent. All inlays were cemented with dual-cured light-activating composite resins.

The patients' opinions about the inlays were overall positive, but six patients reported that their initial amalgam fillings had felt more agreeable. Two patients had persistent hypersensitivity, and one patient with a relatively large number of Optec inlays reported an occlusal disorientation.

At both the first examination and at the reexamination most of the inlays had subgingivally placed margins (Table 2). The number of proximal surfaces with plaque had decreased at the reexamination compared with the first examination (Table 3). However, there was no difference between the two examinations with regard to bleeding on probing. No difference between Optec inlay surfaces or homologous surfaces was seen for proximal plaque (Table 3) or for bleeding on probing at either the first examination or the reexamination.

The examination using the modified criteria of the CDA with regard to Color showed an absolute excellent rating (R0) in 7% at the first examination and 3% at the reexamination. The corresponding ratings for Surface were 14% and 4%; Anatomic Form, 24% and 32%; and Margin Integrity, 67% and 27%, respectively. The number and percentage of inlays that did not receive an excellent CDA rating at the two examinations are presented in Table 4. A slight but detectable color mismatch (R1) between the inlay and the tooth structure had increased by 11% from the first examination to the reexamination, but a more distinct mismatch (SMM) had decreased by 7% between the two examinations. As to Anatomic Form, the most frequent finding was slightly undercontoured marginal ridges (SMR) in 64% and slightly overcontoured restorations (SOCO) in 14% at the first examination. These ratings had decreased at

Table 2. Margin index scores of Optec proximal surfaces

Surface	Score 0	Score 1	Score 2	Score 3
Mesial				
Reex 1 (n = 149)	4	16	26	103
Reex 2 (n = 105)	0	6	27	72
Distal				
Reex 1 (n = 152)	15	6	27	104
Reex 2 (n = 104)	2	5	30	67

Score 0 = restoration margin >2 mm above the gingival margin; score 1 = restoration margin <2 mm above the margin; score 2 = restoration at the gingival margin; and score 3 = restoration below the gingival margin.

Table 3. Relative number and percentage of restored proximal surfaces with plaque

Surface	Optec surfaces		Homologous surfaces	
	Relative no.	%	Relative no.	%
Mesial				
Reex 1	131/149	88	73/73	100
Reex 2	60/101	59	27/47	57
Distal				
Reex 1	139/152	91	53/69	77
Reex 2	59/99	60	34/54	63
Total				
Reex 1	290/301	90	126/142	89
Reex 2	119/200	60	61/101	60

the reexamination. Unacceptable ratings such as missing contact (TCO) and undercontoured interproximal cervical areas (TPX) registered at the first examination were not registered at the reexamination. The most striking difference in rating between the two examinations was seen at the margin. Visible evidence of ditching along the margin (SCR) had increased by 50%. An apparent discoloration on the margin between the restoration and the tooth structure (SDIS) was seen in 73% at the reexamination, compared with 7% at the first examination. All margins with evidence of ditching at the reexamination were also discolored but none of the inlays had unacceptable ratings with regard to margin integrity. The percentage of Optec inlays not receiving an excellent CDA rating with regard to treating dentist is presented in Table 5. Differences in clinical quality of the Optec inlay treatment was noticed between the different dentists, but all of them had more ratings within the range of acceptability than within the range of excellence at the reexamination. No differences were seen between the dental laboratories with regard to the quality ratings.

Discussion

Initially, 205 inlays were examined; 81% of these could be located and reexamined after another 2 years in service in this 3-year plus follow-up study. It was not possible to find out in detail what had happened to the drop-outs, which comprised 39 inlays distributed in 10 patients. Some of the reasons were that the patients had either moved to unknown addresses or refused to participate in the study because of lack of time. It could be argued that the drop-out frequency is high in relation to the short follow-up period. However, as the need for this kind of studies is obvious, the result achieved by screening the remaining 81% will mediate valuable information, even though the conclusions to be gained from the results should be drawn with caution.

Of the 166 Optec inlays initially placed in the 47 patients participating in the reexamination, 13% had fractured and were consequently not examined. The mean time for these inlays in service before fracture was 26.4 months.

A similar fracture frequency, 12%, was reported by Christensen et al. (19) for fired porcelain inlays in a 2-year evaluation. However, several studies have reported considerably lower fracture frequency figures. Isenberg et al. (20) reported a frequency of 5.8% for Vita and Dicor inlays produced by the CAD/CAM technique after a 3-year follow-up. About the same fracture frequency (5.9%) has been reported by Jenssen (21) for Mirage inlays after 2 years. Studer et al. (22) reported an even lower fracture rate, 2.3%, for Empress inlays made by general practitioners. However, the evaluation time was only 18 ± 6 months. This emphasizes the importance of a long follow-up period.

It should be noticed that for two of the dentists, with a fairly low production rate (Table 1), a high failure rate was recorded. About one-third of their produced inlays had fractured, compared with none or a very limited number for dentists with a considerably higher production of inlays. This finding emphasizes the sensitivity of this technique and the dependence on personal operator skill and clinical experience, which may be

Table 4. Percentage of Optec inlays at Reex 1 (n = 205) and Reex 2 (n = 145) that did not receive an excellent CDA rating

	Surface*	Color*			Anatomic form*						Margin integrity*				
		SRO	R1	SMM	SMR	SOCO	SUCO	SOG	SCO	TCO	TPX	SCR	SDIS	TMD	VFR
Reex 1	86	42	52	64	14	4	2	3	1	1	23	7	1	2	2
Reex 2	96	52	45	61	2	6	0	0	0	0	73	73	0	0	0

* SRO = surface of restoration is slightly rough or pitted, can be polished; R1 = small mismatch in color, shade and/or translucency between restoration and adjacent tooth structure; SMM = mismatch between restoration and tooth structure within the normal range of tooth color, shade, and/or translucency; SMR = marginal ridges slightly undercontoured; SOCO = restoration is slightly overcontoured; SUCO = restoration is slightly undercontoured; SOG = occlusal contour not continuous with that of cusps and planes; SOC = contact slightly open (may be self-correcting); TCO = contact is faulty (self-correcting is unlikely); TPX = interproximal cervical area undercontoured: tissue damage likely; SCR = evidence of ditching along the margin, not extending the DE junction; SDIS = discoloration on the margin between the restoration and the tooth structure; TMD = dentin or base is exposed along the margin; VFR = restoration is fractured; VMIS = restoration is missing.

Table 5. Percentage distribution of Optec inlays that did not receive an excellent CDA rating* with regard to treating dentist

Dentist	n	Surface SRO	Color		Anatomic form						Margin integrity						
			R1	SMM	SMR	SOCO	SUCO	SOG	SCO	TCO	TPX	SCR	SDIS	TMD	VFR	VMIS	
A _{reex1}	14	43	79	21	14	29	7						71	14			
A _{reex2}	9	89	89	22	56	11	11						78	78			
B _{reex1}	4	100	75	—	75	—	—						—	25	25		
B _{reex2}	4	100	100	—	75	—	—						100	100			
C _{reex1}	36	92	53	28	44	11	—	6					8	3			
C _{reex2}	35	100	82	11	20	3	6						20	29			
D _{reex1}	8	100	75	—	38	—	13	25					75	—			
D _{reex2}	6	100	—	100	67	—	17						100	100			
E _{reex1}	20	85	50	40	85	10	—						30	5			
E _{reex2}	12	100	58	33	67	8	—						92	—			
F _{reex1}	11	—	82	9	—	18	9						9	—			
F _{reex2}	8	63	88	13	—	—	—						50	50			
G _{reex1}	9	100	44	44	100	44	—						11	—			
G _{reex2}	7	100	14	71	100	—	—						43	—			
H _{reex1}	17	94	35	65	59	—	—				6	6	35	35	6	12	6
H _{reex2}	8	100	38	63	88	—	—						100	100			
I _{reex1}	51	94	10	90	75	6	8				10		20	8			
I _{reex2}	35	97	29	71	77	—	11						100	100			
J _{reex1}	35	100	34	66	94	26	6				6		14	17			
J _{reex2}	21	100	29	71	95	—	—						100	100			

* The abbreviations of the ratings are explained in Table 4.

much more important than in other prosthetic procedures. The choice of dental laboratory did not seem to have any impact on achieved clinical performance.

The fractured inlays were of class-II type, and most were seated in molars. However, the fact that 59% of the inlays at the first examination were placed in the molar region may explain why most of the fractured inlays also were in molars. It has been suggested that porcelain inlays are contraindicated in patients with bruxism. Eighty per cent of the patients at the first examination showed signs of moderate to severe wear of the occlusal surfaces, and more than 30% of the patients showed signs and symptoms from the temporomandibular system, indicating that bruxism could have taken place. All patients with fractured inlays at the reexamination had moderate to severe occlusal wear, which could be one possible explanation of and contributory factor to the fractures. Fracture strength has also been related to the surface porosity of porcelain, which may be induced by bruxism and related wear.

The brittle nature of fired porcelain inlays requires adequate bonding between porcelain and tooth. In vitro studies have reported lower fracture strength values for ceramic inlays luted with glass ionomer cement than for composite resin luting materials (9, 23, 24). This has also been confirmed in a 3-year follow-up study by Höglund et al. (15), who reported a higher fracture frequency for glass ionomer-luted porcelain inlays than for inlays luted with composite resin. However, in the present study the fracture frequency was high even though all inlays had been luted with dual-cured composite resin luting agents. Factors such as fit,

occlusal force, cavity design, and luting technique are all of great importance for the longevity of ceramic inlays, possibly of greater importance than the luting material.

Almost all studies of tooth-colored inlays have reported postoperative hypersensitivity as a major problem. Factors such as cavity treatment, luting medium, bacterial invasion, and pulp inflammation but also piezoelectricity have been presented as possible explanations of this phenomenon (25, 26). In the present material eight patients (14%) reported postoperative hypersensitivity at the first examination, whereas at the reexamination the hypersensitivity persisted for only two of the patients examined. As we cannot predict anything about the patients not examined at the reexamination, this difference should be considered with caution. However, provided the occlusion is correct, the hypersensitivity after ceramic inlay therapy seems to be a passing problem for most patients.

A notable finding at the reexamination, compared with the first examination, was the significant increase of ditching along the margin between tooth and inlay. This observed clinical sign of deterioration over time is in agreement with other follow-up studies (15). Likewise, discoloration of the margin was present more frequently at the reexamination. This is, however, in contrast to some other studies (15, 19, 20). Reasons for this recorded difference in frequency are obscure, but explanatory factors may be different resin cements used for luting and variety in the dentists' handling of the material. Mechanical and chemical degradation of the exposed superficial luting cement seems to accelerate after the 1st year in service, as indicated in the present

study. This is probably caused by wear/abrasion, enzymatic influence, hydrolysis, and subsequent microleakage (3, 7, 8, 12, 14, 19, 20). Known drawbacks of resin cements are their process of aging combined with susceptibility to hydrolysis. A sequel to this mechanism could be an adhesive failure, initiated by a debonding process in the dentin-ceramic interface, and could be a possible explanation of both discoloration and ceramic fractures, often seen after 3–4 years in service. Another possible predictor of a ceramic fracture is microcracks and surface porosities, either created during the manufacturing process or grinding/polishing or due to occlusal wear. A rough appearance of the occlusal surface was also more often registered at the reexamination, and only time will show the clinical significance of this finding. In summary, the frequency of several factors of negative importance for ceramic inlay longevity seems to have increased significantly between the first examination and the reexamination. A great deal, however, can be related to the treating dentist and the used technique and skill. The failure rate, however, is so far within reasonable limits, although this treatment is not as successful as therapy with gold inlays (27). Future examinations will further substantiate and establish the long-term outcome of this kind of prosthetic rehabilitation.

References

1. Qualtrough AJE, Cramer A, Wilson NHF, Roulet J-F, Noack M. An in vitro evaluation of the marginal integrity of a porcelain inlay system. *Int J Prosthodont* 1991;6:517–23.
2. Molin M, Karlsson S. The fit of gold inlays and three ceramic inlay systems. A clinical and in vitro study. *Acta Odontol Scand* 1993;51:201–6.
3. Thordrup M, Isidor F, Hörsted-Bindslev P. Comparison of marginal fit and microleakage of ceramic and composite inlays: an in vitro study. *J Dent* 1994;22:147–53.
4. Hahn R. Experimental studies on the reproducible precision of fit of ceramic inlays. *Dtsch Zahnärztl Z* 1990;45:5653–6.
5. Van-Meerbeek B, Inokoshi S, Willems G, Noack MJ, Braem M, Lambrechts P, et al. Marginal adaptation of four tooth-coloured inlay systems in vivo. *J Dent* 1992;20:18–26.
6. Lu R, Harcourt JK, Tyas MJ, Alexander B. An investigation of the composite resin/porcelain interface. *Austr Dent J* 1992;37:12–9.
7. Sörensen JA, Kang SK, Avera SP. Porcelain-composite interface microleakage with various porcelain surface treatments. *Dent Mater* 1991;7:118–23.
8. Blair KF, Koeppen RG, Schwartz RS, Davis RD. Microleakage associated with resin composite-cemented, cast glass ceramic restoration. *Int J Prosthodont* 1993;6(6):579–84.
9. Dietschi D, Maeder M, Meyer JM, Holz J. In vitro resistance to fracture of porcelain inlays bonded to tooth. *Quintessence Int* 1990;21:823–31.
10. Bessing C, Molin M. An in vivo study of glass ceramic (Dicor®) inlays. Preliminary report. *Acta Odontol Scand* 1990;48:351–7.
11. Sjögren G, Bergman M, Molin M, Bessing C. A clinical examination of Cerec® ceramic inlays. *Acta Odontol Scand* 1992;50:171–8.
12. Molin M, Karlsson S. A clinical evaluation of the Optec inlay system. *Acta Odontol Scand* 1992;50:227–33.
13. Stenberg R, Matsson L. Clinical evaluation of glass ceramic inlays (Dicor). *Acta Odontol Scand* 1993;51:91–7.
14. Thordrup M, Isidor F, Hörsted-Bindslev P. A one-year clinical study of indirect and direct composite and ceramic inlays. *Scand J Dent Res* 1994;102:186–92.
15. Höglund Åberg C, van Dijken J, Olofsson A-L. Three-year comparison of fired ceramic inlays cemented with composite resin or glass ionomer cement. *Acta Odontol Scand* 1994;52:140–9.
16. Silness J. Periodontal conditions in patients treated with dental bridges. *J Periodontol* 1970;5:60–8.
17. Lenox JA, Kopczyk RA. A clinical system for scoring a patient's oral hygiene performance. *J Am Dent Assoc* 1973;86:849–52.
18. Quality evaluation for dental care. Guidelines for the assessment of clinical quality and professional performance. Los Angeles: California Dental Association, 1977.
19. Christensen R, Christensen G, Vogel S, Bangerter V. Two-year clinical evaluation of 6 inlay systems [abstract 2360]. *J Dent Res* 1991;70:561.
20. Isenberg BP, Essig ME, Leinfelder KF. Three year clinical evaluation of CAD/CAM restorations. *J Esth Dent* 1992;4:173–6.
21. Jenssen ME. A two-year clinical study of posterior etched-porcelain resin-bonded restorations. *Am J Dent* 1988;1:27–33.
22. Studer S, Lehner C, Schärer P. Glass ceramic inlays and onlays made by IPS-Empress [abstract 1144]. *J Dent Res* 1992;71:658.
23. Stangel I, Nathanson D, Hsu CS. Shear strength of the composite bond to etched porcelain. *J Dent Res* 1987;66:1460–5.
24. Dérand T. Stress analysis of cemented or resinbonded loaded porcelain inlays. *Dent Mater* 1991;7:21–4.
25. Council on Dental Materials, Instruments and Equipment. Biocompatibility and postoperative sensitivity. *J Am Dent Assoc* 1988;116:767–8.
26. Sjögren G, Bergman M, Johansson K. Piezoelectricity in dental materials, a conceivable cause of postrestorative sensitivity. *Acta Odontol Scand* 1992;50:313–9.
27. Nordbö H, Lyngstadaas SP. The clinical performance of two groups of functioning class-II cast gold inlays. *Acta Odontol Scand* 1992;50:189–92.

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