A four to six years follow-up of indirect resin composite inlays/onlays

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The objective of this clinical survival study was to evaluate the performance of indirect resin composite inlays and onlays. Patients were recruited among the dental school clientele needing posterior approximal restorations and preferring esthetic restorations. Two clinical teachers and 6 trained students under supervision carried out the preparations, made impressions, and prepared stone casts. Inlays/onlays from Tetric®, Z100®, or Maxxim® were light-cured and transferred to a light oven for secondary curing. At the 4–6 year recall, the inlays/onlays were evaluated using slightly modified US Public Health Service criteria, bitewing radiographs, and plastic dies based on replica impressions. All 25 treated patients with a total of 64 inlays/onlays presented for the assessment. The right-censored observation periods ranged from 48 to 75 months, with a mean of 59. With the exception of three failed inlays/onlays scored as 'D' (2 fractures, 1 caries), i.e. 5%, the majority were classified as successful. This was based on 43 'A' (optimal) and 18 'B' (acceptable) ratings, each of which represented the lowest rating for each individual restoration. The major reason for 'B' ratings was imperfect anatomical form, mostly absence of proximal contacts. The present clinical trial demonstrated that inlays/onlays made from Tetric, Z100, and Maxxim performed equally well over the 5-year period. Within the limits of this study it is concluded that the resin composite inlay/onlay technique should be considered as an alternative to direct fillings in the approximal posterior region. □ *Class II restorations; clinical trial; dental materials; esthetic restorations; operative dentistry*

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The use of resin composite restorations in operative dentistry has gradually increased during the past decade—partly due to improvements in the materials themselves and partly to changes in restorative techniques. Other factors include a greater demand for 'esthetic' restorations and the current debate on the 'amalgam issue'.

Despite incremental build-up of resin composite restorations, polymerization shrinkage of the resin during curing is still considered to be a major problem contributing to marginal defects, cuspal distortion, crack formation, and propagation within the tooth tissues, resulting in postoperative sensitivity. Other factors, such as the distance and orientation of the light source, light intensity (1), and color of the material (2), may affect polymerization in deep areas and may lead to partly cured areas, susceptible to washout and leakage.

In an attempt to overcome some of the problems associated with the direct placement technique, an indirect inlay technique has been developed (3). Polymerization shrinkage takes place outside the mouth, thus limiting the shrinkage to that of the thin luting cement layer. Post-curing at a high temperature results in a higher stress relaxation and degree of conversion compared to the directly placed light-cured resin composite restoration (4–8). By the inlay/onlay technique, gap formation around resin composite inlays could be prevented (9), and improved marginal adaptation and seal of the inlays have been reported (7, 10, 11).

In the present clinical trial a previous evaluation (50 inlays/onlays; 20 ± 8 months) showed a failure rate of 2%, whereas the successful restorations scored either 'A' (31%) or 'B' (69%) (12). The aim of this article is to evaluate the feasibility of resin composite inlays/onlays by presenting the 4–6 year assessment of an extended material of restorations.

Materials and Methods

Patients in need of posterior approximal restorations and preferring esthetic restorations were concecutively recruited among patients attending the Department of Cariology at the Dental Faculty, University of Oslo during the period 1995–1997. No further selection was made. The cavities were classified as medium-sized/large, since the proximal boxes generally extended (to a variable extent) on to the buccal and/or the lingual surfaces. Twenty-one women and 4 men participated, and a total of 64 preparations were carried out. Fifty-six were made by two clinical teachers, and 8 by 6 trained students. All steps performed by the students were supervised by the teachers. Onlays were chosen when, in addition to wide proximal boxes, the occlusal width of the cavity extended more than half the distance between the buccal and the lingual cusp tips (Table 1).

All cases were replacements of unsatisfactory or failed Class II amalgam or directly placed resin composite restorations. After removal of old fillings and decayed tooth structure, box-shaped inlay cavities with rounded angles were prepared. Eighty-five percent of the cavities

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Table 1. Localization and number of ratings for the different types of indirect resin composite inlays/onlays

	2-surface			3-surface		Onlay			Total no.
Ratings	'A'	'B'	'D'	'A'	'B'	'A'	'B'	'D'	49
Premolars (no.)	13	1	1*	11	7	8	7	1†	15
Molars (no.)	6	1	1‡	2	3	2	64§		
Total no.		23			20		21		

* Caries lesion.
† Fractured tooth.
‡ Restoration replaced by gold.
§ Thirty-four restorations in the upper, 30 in the lower jaw. Chi-square tests showed a significant difference in success rates between 2-surface and 3-surface/onlay restorations (chi-square = 6.148. d.f. = 1.0.02 > P > 0.01), but not between premolars and molars.

were finished with enamel margins all around the cavo-surface angle, which was not beveled. Elastomeric impressions (Permadyne/Impregum Penta, Espe, Seefeld/Oberbay, Germany) were taken for preparation of stone casts.

Three brands of composite resin materials commonly used in the clinic were used in this study. Thirty-five of the inlays/onlays were made of *Tetric* (Vivadent, Schaan/Liechtenstein, batch no. 800024), 16 of *Z100* (3 M Dental Product Division, St. Paul, Minn., USA, batch no. 20001-0131), and 13 of *Maxxim* (Ceramco Headquarters, Burlington, N.J., USA, batch no. 951024). All the materials are hybrid small-particle materials.

The inlays/onlays were produced as earlier described by Leirskar et al. (12). Briefly, the restorations were built up on stone models and post-cured in a light- and heat-curing oven (Dentsply. York, Pa., USA). The walls of the tooth cavity were etched and primed (Syntac, Vivadent, for Tetric; Scotchbond Multi-Purpose, 3 M, for Z100 and Maxxim) in accordance with the recommendations of the manufacturers. The inlays/onlays were sand-blasted for 1 min by Al_2O_3 in a micro-etcher (Micro Cab, Danville Engineering Inc., San Ramon, Calif., USA) and coated with a silane solution (Ultradent Silane, Ultradent Products Inc., Ut., USA). The restorations were luted with a dual-cure cement (Dual-Cement Radiopaque, Vivadent), adjusted to occlusion and articulation, and finished as previously described (12).

Sixty-two of the original 64 restorations, with observation periods of 4 years (25 restorations), 5 years (28 restorations), and 6 years (9 restorations) were evaluated concomitantly by three of the authors (non-operators) using slightly modified US Public Health Service (USPHS, Table 2) criteria for clinical evaluation (13). Fifty of these

Table 2. Criteria for clinical evaluation

Category	Optimal	Acceptable	Unacceptable	Criteria
Anatomical form	A			The restoration is contiguous with tooth anatomy.
	B			Slightly under- or over-contoured restoration; contact slightly open (may be self-correcting); occlusal height reduced locally.
			C	Restoration is undercontoured; dentine or base exposed; contact is faulty and not self-correcting; occlusal height reduced; occlusion affected.
			D	Restoration is missing, traumatic occlusion; restoration causes pain in tooth or adjacent tissue.
Marginal adaptation	A			Restoration is contiguous with existing anatomical form; explorer does not catch.
	B			Explorer catches; visible evidence of crevice; enamel exposed.
			C	Dentine or base is exposed along the margin.
			D	Restoration mobile, fractured or missing.
Marginal discoloration	A			No discoloration evident.
	B			Slight staining.
			C	Obvious staining; cannot be polished away.
			D	Gross staining.
Color match	A			Good color match.
	B			Slight mismatch in color, shade, or translucency.
			C	Obvious mismatch, outside the normal range.
			D	Gross mismatch.
Surface roughness	A			Smooth surface.
	B			Slightly rough or pitted.
			C	Rough, cannot be refinished.
			D	Surface deeply pitted; irregular grooves.
Caries	A			No evidence of caries contiguous with the margin of the restoration.
			D	Caries contiguous with the margin.

restorations had been evaluated after 20 ± 8 months of service (12). The 14 'new' inlays/onlays, now included, were excluded in the previous report because of too short periods of service. The patients attended general dental care, but had no additional evaluations in the period between the two assessments.

For comparison, bitewing radiographs were simultaneously evaluated with emphasis on secondary gingival caries, gap formation, voids, overhangs, and underfilling. Dies (CIBA XW 396, Lindberg & Lund AS, Vestby, Norway) based on replica impressions (Permadyne/Impregum Penta) were examined separately by two of the authors at up to 5× magnification with a stereomicroscope (Olympus SZ40, Japan). These examinations might reveal poor marginal adaptation, surface porosities, defective marginal ridges, and lack of proximal contact. The lowest rating recorded by the three evaluation methods was assigned to each restoration. Fourteen inlays/onlays (i.e. 23%) in two patients were re-evaluated by a recall. Reproducibility of the clinical and radiographic evaluation methods was found to be 99%.

Survival analyses and testing of differences between the three materials were planned, but the exceptionally high success rate precluded this. Chi-square tests were used to test differences in distribution of ratings between premolars/molars and small/large restorations.

Results

The mean age of the patients at the final assessment in this extended study was 48 years (range 27–80), and the mean age of the restorations at the time of evaluation was 59 months (range 48–75). During the observation period one restoration was lost due to fracture of the tooth, and one had been replaced by a gold restoration due to fracture of the marginal ridge. Caries was found contiguous with the margin of one restoration. This means a failure rate of 5% (Tables 1 and 3). One replica impression was lost. The restoration of this tooth, however, was rated as optimal by both the clinical and the radiographic evaluations. Thus, 61 inlays/onlays were classified as optimal or acceptable (Table 3). No difference was detected between the three materials concerning clinical performance.

Twenty-two percent of the 64 restorations were classified as 'B' (acceptable quality, requiring minimal corrections) by the clinical examination, whereas only 16% of the restorations were similarly rated by the replica and the radiographic evaluation methods. When combining the ratings of the evaluation methods, 28% of the restorations achieved a 'B' score (Table 3). The 2-surface restorations showed a significantly higher success rate than the 3-surface restorations and the onlays. There was, however, no statistically significant difference in success rate between premolar and molar restorations (Table 1).

The major reason for 'B' ratings was imperfect anatomical form, mostly due to acceptable, but not optimal proximal contacts. The second most frequent 'B' rating was inadequate marginal adaptation, mostly due to thin approximal overhangs of bonding material and/or luting cement, which could easily be corrected. No 'B' rating was applied for surface roughness, marginal discoloration, or color match (Table 4). 'B' ratings were equally distributed among the three materials.

Complete agreement among the 'A' (optimal quality) and 'B' scores obtained by the 3 evaluation methods (clinical, replica, and radiographic) was found for 46 of the 61 restorations.

Discussion

The participants were a convenience sample from among those seeking moderately priced treatment at the Dental Faculty. The share of fully working employees was high. The high proportion of women is not considered important for the results.

The three evaluation methods used in this study focused to some extent on different clinically relevant qualities of the restorations. The clinical evaluation mainly focused on anatomical form, color, and marginal adaptation. The radiographs were used to reveal caries and control the gingival interface between restoration and tooth. Replicas gave information about occlusal ditching, surface texture, and proximal contact. However, they did not give much additional information and were found to constitute the least informative evaluation method. They were therefore not re-evaluated. The evaluation methods measured different qualities of the restorations, and this may explain why the agreement was only modest (12).

The proportion of the overall 'B' ratings dropped from 69% to 28% from the previous (12) to the present

Table 3. Ratings obtained by the three scoring methods. Comparison of results from the previous and the present evaluations

		Previous evaluation		Present evaluation	
Method	Rating	No.	%	No.	%
Clinical	A	20	41	47	73
	B	29	59	14	22
	D	1*	2	3†	5
Replica‡	A	26	53	51	84
	B	23	47	10	16
Radiographic§	A	38	78	52	84
	B	11	22	10	16
Overall results	A	15	31	43	67
	B	34	69	18	28
	D	1*	2	3	5

* Partial fracture of the resin composite cusp after 1 month; adjusted by grinding, still in service.
† One carious lesion, one fractured tooth, and one restoration replaced by gold.
‡ One replica impression missing. No replicas for fractured tooth and restoration replaced by gold inlay.
§ No radiographs for fractured tooth and restoration replaced by gold inlay.

Table 4. Deficiencies resulting in 'B' ratings and comparison between the previous (50) and the present (64) restorations

	Evaluation method					
	Clinical		Replica		Radiographic	
Type of defect	Previous evaluation	Present evaluation	Previous evaluation	Present evaluation	Previous evaluation	Present evaluation
Anatomical form	11	10	11	7	5	9
Marginal adaptation	25	5	15	3	6	2
Marginal discoloration	4	0	–	–	–	–
Color match	1	0	–	–	–	–
Surface roughness	3	0	5	0	–	–
Caries	0	1	–	–	0	0
Total	44	16	31	10	11	11

evaluation, and the distribution of the different shortcomings had shifted. Imperfect gingival marginal adaptation (mostly overhangs) was found to be most common in the 2-year evaluation, whereas anatomical form was most frequent in the 4–6 year evaluation (Table 4). The removal of the observed overhangs at the first evaluation was deemed to be the reason for the improvements found at the present evaluation. A surplus of thin layers of cement and bonding material, adhering to the tooth, is difficult to observe at the initial stage, because of its translucency and adherence to the tooth surface, whether etched or not. Over time, the surplus outside the etched area may loosen and fracture, making it easier to disclose. Corrections also eliminated the previously observed marginal discolorations.

In the present study, most of the 'B' ratings were caused by imperfections in anatomical form, and this was consistent for all evaluation methods. The dominating error was inadequate proximal contact, probably because of improper initial contouring of the restoration.

Surface roughness and wear were found to be negligible and did not justify any 'B' rating. Color match was always within the 'A' category (Table 4). As might be expected, two-surface restorations performed better than the larger ones. This might be related to the less masticatory load, shorter marginal periphery of the restoration, and less destructive intervention used in the former treatment modality.

The overall results of the present study showed a failure rate of 5%. By comparison, a failure rate of 7% was found after 3 years in a similar study where dental students, under the supervision of an experienced dentist, placed 45 indirect resin composite inlays in posterior teeth (14). In a 6-year clinical trial of 100 direct resin composite inlays, van Dijken (15) reported that only 6% had failed and needed replacement. After 11 years van Dijken (16) found a failure rate for inlays/onlays of 8.3%. Other investigators report annual failure rates of composite inlays and onlays in posterior stress-bearing restorations ranging from 0% to 11.8% (17). Directly placed composite resin fillings in saucer-shaped cavities showed a replacement rate of 18% and 31% after 3 and 10 years of service, respectively (18).

Only one small secondary carious cavity was found. Thus, caries did not represent a threat to these restorations, neither at the 2-year nor at the 5-year evaluation. No special measures had been taken to select patients with a low caries risk, although they were given routine preventive treatment. This finding is consistent with the results of van Dijken (16), who found only 4.2% secondary carious lesions related to composite resin inlays after 11 years of service. However, higher caries rates have been reported (19). It must be taken into account, that secondary caries is primarily a consequence of marginal adaptation and the patient's general caries activity (20). Also the restorations in molars performed well, since only 1 out of the 15 failed.

Within the time limits of this study it can be concluded that the resin composite inlay/onlay technique represents a suitable treatment modality for restoring medium sized/large cavities or replacing failed amalgam or directly placed resin composite restorations in posterior teeth. However, Pallesen's (19) and van Dijken's (16) results indicate that inlays/onlays do not have long-term advantages over direct fillings. Also Wassel et al. (21) found, after 5 years, no clinical advantage of direct resin composite inlays over conventional, incrementally placed restorations. More clinical research is therefore needed to justify as a matter of routine the more time-consuming and expensive resin composite inlay/onlay technique.

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