Clinical performance of indirect composite resin inlays/onlays in a dental school: observations up to 34 months

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Leirskar J, Henaug T, Thoresen NR, Nordbø H, von der Fehr FR. Clinical performance of indirect composite resin inlays/onlays in a dental school: observations up to 34 months. Acta Odontol Scand 1999;57:216–220. Oslo. ISSN 0001-6357.

The aim of this retrospective clinical study was to evaluate the clinical performance of indirect composite resin inlays and onlays. Patients among the dental school clientele in need of posterior approximal fillings and preferring esthetic restorations were included. Clinical teachers or trained students under supervision carried out the preparations, made impressions and prepared stone casts. Inlays made from either Tetric®, Z100® or Maxxim® were light-cured and placed in a light oven for secondary curing, before being luted with a dual cure cement. At recall, the inlays were evaluated using slightly modified US Public Health Service (USPHS) criteria. Twenty-two patients with 50 fillings presented for the assessment. The right censored observation periods ranged from 12 to 34 months, with a mean of 20. With the only exception of an early fracture of one onlay, all restorations were classified as successful. This was based on 15 “A” (optimal) and 34 “B” (acceptable) ratings, each of which representing the lowest rating for the individual restoration. The major reason for the “B” ratings was imperfect gingival marginal adaptation due to a small surplus of bonding material and/or luting cement. □ *Class II restorations; clinical trial; dental materials; esthetic restorations; operative dentistry*

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Direct composite resin restorations are the most common alternative to dental amalgam in Class II cavities. However, polymerization shrinkage of composite resins represents a problem, since it may lead to gap formation between the restorative material and the cavity walls. Furthermore, optimal polymerization may be difficult to achieve in deep interproximal areas and result in insufficiently cured restorations susceptible to dissolution and bacterial ingress (1).

Using an inlay technique, the polymerization shrinkage problem can be substantially reduced (2). Since most of the shrinkage takes place during the curing of the inlay, the only shrinkage is that of the thin luting cement layer. Post-curing in a light- and heat-curing oven also promotes a higher degree of polymerization, which may to some degree augment the mechanical and physical properties of the material (3–5). Another advantage suggested is better integrity of the tooth/restoration interface (6–8), which can result in increased longevity and reduced marginal leakage.

The clinical performance of composite resin inlays has been studied recently. Wassel et al. (9, 10) compared direct composite resin inlays with conventional composite restorations and found little overall clinical difference after 3 and 5 years. A 6-year follow-up study of 100 direct composite resin inlays and onlays found the clinical durability to be good (11). Based on a general clinical evaluation and the rate of degradation of the margins, the longevity of tooth-colored inlays was estimated to be at least 10 years (12). Despite the fact that almost half of the patients participating in that study were considered to be at high caries risk, recurrent caries was reported to be rare. In a clinical evaluation of conventional composite resin fillings and indirect inlays, no statistical difference was found between the restorations, although the overall assessment indicated a better performance of fillings than inlays after 8 years (13). Inlays were generally superior to direct fillings when dealing with fracture and porosity/crack formation.

The aim of the present investigation was to study the clinical performance of composite resin inlays using the indirect inlay technique.

Materials and methods

Patients in need of posterior approximal fillings and with a preference for esthetic restorations were selected among patients attending the Department of Cariology at the Dental Faculty, University of Oslo. Forty-four out of a total of 50 preparations were carried out by 2 clinical teachers, and 6 by trained students. However, all steps performed by students were supervised by the clinical teachers, who performed the baseline approval. With the exception of the onlays, the Class II restorations could be classified as medium-sized, i.e. the occlusal width of the restoration extending not more than one-third of the distance between the buccal and lingual cusp tips.

The majority of the restorations were placed in premolar teeth (Table 1). All were replacements of unsatisfactory or failed Class II amalgam or direct composite resin restorations. After removal of old fillings

Table 1. Type and localization of the indirect composite resin inlays/onlays

	Type of inlay			
	2-surface	3-surface	Onlay	Total
Premolar	13	17	9	39
Molar	7	1	3	11
Total*	20	18	12	50

* Equally distributed between the upper and the lower jaw.

and decayed tooth structure, box-shaped inlay cavities, with rounded internal angles, were prepared. Most of the cavities (about 85%) were finished with enamel margins, and the margins were not beveled. Elastomeric impressions (Permadyne/Impregum Penta, Espe, Seefeld/Oberbay, Germany) were taken for preparation of stone casts.

Three brands of composite resin materials, which are commonly used in the clinic, were used in this study. Thirty-five of the inlays/onlays were made of *Tetric* (Vivadent, Schaan/Liechtenstein, batch number 800024). *Z100* (3M Dental Products, St. Paul, MN, USA, batch number 2002–0131) and *Maxxim* (Ceramco Headquarters, Burlington, NJ, USA, batch number 951024) were used in 7 and 8 inlays/onlays, respectively. All the materials are hybrid small-particle materials. Because of the low total number of restorations included in the study, no differentiation between the materials will be made at this stage.

A model release agent (*Triad*®, Dentsply, York, PA, USA) was applied to the stone model cavities, and the inlays were built up in increments followed by 40 s of visible light-curing (Demetron Research Corporation, Danbury, CT, USA). The inlays were then removed from the cavities and post-cured in a Triad 2000 light- and heat-curing oven (Dentsply, York, PA, USA) for 7 min at 120°C.

After a try-in of the inlays/onlays to verify the fit, the prepared teeth were isolated by rubber dam before cementation. Transparent matrix and light-conducting wedges (Luciwedge, Hawe Neos Dental, Gentilino, Switzerland) were used to ensure gingival adaptation and tooth separation. After acid-etching (37% phosphoric acid gel for 20–30 sec), thorough spraying with water for 30 sec and light air-drying, the dentine adhesives were applied in accordance with the recommendations given by the manufacturers. *Syntac* (Vivadent) was used in combination with Tetric, and *Scotchbond Multi-Purpose* (3M Dental Products) in combination with Z100 and Maxxim.

Before luting with a dual-cure cement (Dual-Cement Radiopaque, Vivadent) the inner surface of the inlays was sand-blasted for 1 min with Al_2O_3 (particle size 50γ) in a micro-etcher (Micro Cab, Danville Engineering Inc., San Ramon, CA, USA) and coated with a silane solution (Ultradent Silane, Ultradent Products Inc. Utah, USA) in accordance with the manufacturer's instructions. The cement was applied to the cavity and the inner surface of the inlay before quick insertion with minimal pressure. Surplus of the cement was removed before a 60 sec light-activation on each surface.

Occlusion and articulation were checked before the inlays were finished with fine-particle diamonds, carbide burs, polishing stones, Profin diamond tips (Dentatus AB, Sweden), and polishing strips (Soflex, 3M Dental Products). At this stage, the inlays/onlays generally showed an "Alfa" rating, except for a few cases where the proximal contacts were rated "Bravo".

Forty-nine of the original 50 restorations in 22 patients (4 men and 18 women), with observation periods of at least 1 year, were evaluated clinically by 2 of the authors using slightly modified (see Table 2) US Public Health Service (USPHS) criteria for clinical evaluation (14). Each restoration was clinically rated for anatomic form, marginal adaptation, marginal discoloration, color match, surface roughness, and caries.

Bitewing radiographs were taken and evaluated with emphasis on secondary gingival caries, gap formation, voids, overhangs, and underfilling (Fig. 1). Dies (Stycast 1266, Grace NV, Westerlo, Belgium) based on replica impressions (Permadyne/ Impregum Penta) were studied at up to 50× magnification with a stereomicroscope (Olympus SZ40, Japan). These examinations would reveal poor marginal adaptation, porosities in the surface, defective marginal ridges, and lack of proximal contact. To test the reliability of the recordings, spot tests were performed by the two examiners. The lowest rating recorded by the 3 evaluation methods was assigned to each restoration.

Results

The mean age of the patients was 44 years (range 23–76); mean age of the restorations at the time of examination was 20 months (range 12–34). The distribution of 1, 2, and 3 year old inlays/onlays is given in Table 3. During the observation period only one restoration failed due to a fractured buccal cusp of an onlay. This happened during the 1st month of service. The remaining 49 inlays were classified as optimal or acceptable by all 3 evaluation methods (Table 4). No difference in clinical performance was detected between the materials.

The clinical evaluation was the most sensitive method, and the radiographic the least sensitive. While 59% of the restorations were classified as "B" ("Bravo", acceptable quality, requiring minimal corrections) by the clinical examination, only 22% were similarly rated by the radiographic evaluation. Thin overhangs, which accounted for most of the discrepancies, proved to be difficult to discover by X-ray. When combining the ratings of all 3 evaluation methods, 69% of the restorations achieved a "B" score (Table 4).

Imperfect gingival, marginal adaptation was found to be the most common defect. This was usually due to thin overhangs of bonding material and/or luting cement,

Table 2. Criteria for clinical evaluation

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

which could easily be removed (Fig. 2). The second most frequent "B" rating was inadequate anatomic form, mostly due to acceptable, but not optimally rated proximal contacts. Marginal discoloration and ditching were rare, and only one "B" rating was applied for color match. No recurrent caries related to the inlays was found (Table 4).

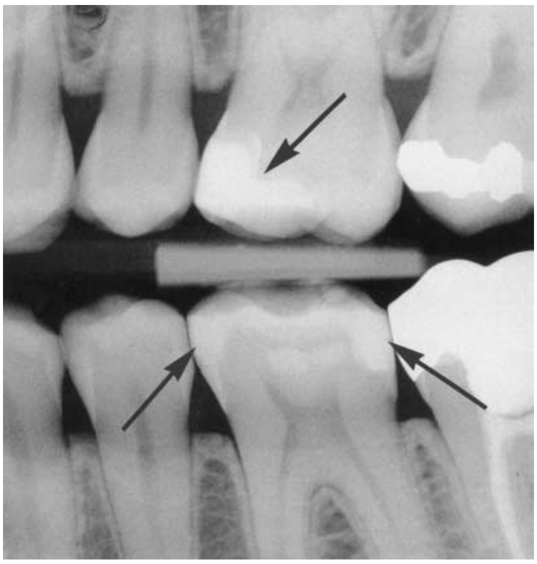

Fig. 1. Composite resin inlays (black arrows), 2 years old, radiographically rated as "A" (optimal quality), in the upper (MO) and lower (MOD) first molars.

Complete agreement among the "A" ("Alfa", optimal quality) and "B" scores obtained by the 3 evaluation methods (clinical, replica, and radiographic) was found only for 20 of the 49 restorations. Concerning the agreement between the clinical and the replica evaluation methods, 33 of the 49 restorations gave the same rating.

Discussion

The present retrospective study is planned for follow up by later evaluations. The indirect inlays/onlays were produced under dental school conditions, which may be different from a busy everyday private practice. This should be borne in mind when evaluating the results.

The 3 evaluation methods focus to some degree on different, but clinically relevant, qualities of the restorations. Thus, the gingival interface between filling and tooth structure was controlled by bitewing radiographs, whereas replicas are not suitable giving much information about this area. This explains why the level of agreement among the methods was modest (15). However, the ratings appear

Table 3. Distribution of 1, 2, and 3-year-old inlays/onlays

Age (years)	No.
1	18
2	24
3	7

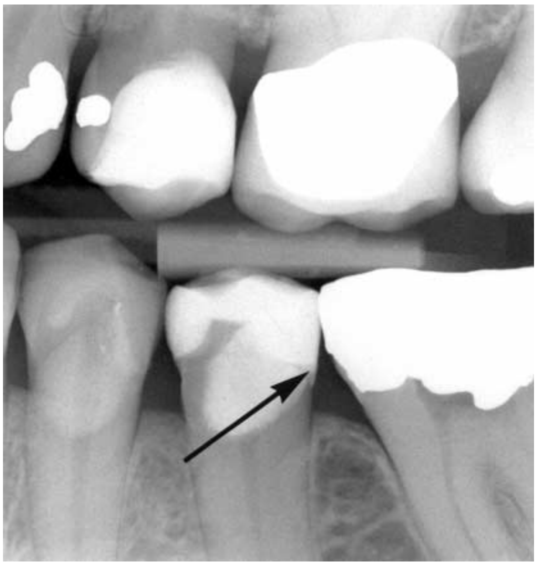

Fig. 2. Composite resin onlays, 2.5 years old, in the upper and lower second premolars. The upper onlay was radiographically rated as "A" (optimal quality) and the lower as "B" (acceptable quality, requiring minimal corrections), because of a surplus (black arrow) of cement and/or bonding material distogingivally (the buccal filling is not related to the inlay).

to justify the conclusion that virtually all of the restorations were clinically acceptable after 20 ± 8 months in service.

The use of gingival wedges is essential if overhangs are to be prevented. With cavity margins in cementum, Neiva et al. (16) found significantly more marginal leakage with a polymerization technique using reflective wedge and clear matrix band than by using metal matrix band and a polymerization technique with a collimator cone. Several authors (17, 18), however, have found that laterally reflective light wedges induce significantly better marginal restoration quality of composite resin restorations gingivoproximally.

Cementation of composite resin inlays is complex and time-consuming (2). In the present study we used both laterally reflecting wedges and a clear matrix band in the cementation procedure. However, this method did not seem adequate to provide optimal proximal adaptation in all cases, since small overhangs and imperfect anatomic form were the most frequent inadequacies observed (Table 5). Both are technique-related.

Table 4. Ratings obtained by the 3 scoring methods

Method	Rating*	Total	%
Clinical	A	20	41
	B	29	59
	D	1†	2
Replica	A	26	53
	B	23	47
Radiographic	A	38	78
	B	11	22
Overall results	A	15	31
	B	34	69

* United States Public Health Service criteria (14): "A" = Alfa (optimal quality); "B" = Bravo (acceptable quality, but with one or more slight deviates from optimal conditions). †Failure after 1 month of service.

Table 5. Deficiencies resulting in "B" ratings*

Type of defect	Evaluation method: Clinical	Replica	Radiographic
Anatomic form	11	11	5
Marginal adaptation	25	15	6
Marginal discoloration	4	–	–
Color match	1	–	–
Surface roughness	3	5	–
Caries	0	–	0
Total	44	31	11

* Some restorations showed more than one deficiency.

Surplus of thin layers of cement and bonding material, adhering to the tooth, is difficult to diagnose because of its translucency. Outside the etched area, some of the surplus may over time fracture in small pieces, making it easier to disclose. Thus, the deficiencies of the marginal adaptation were usually due not to gap formation, but to excess of bonding material and/or luting cement, which could easily be detected and removed after some time of clinical service (Fig. 2). No adverse effect on gingival tissue was detected.

It is well known that tooth cusps may flex under masticatory stress, and that porcelain is less flexible than composite resin. Marginal ditching has been reported in 3-year and 5-year reports of ceramic inlays (19, 20). In the present study, almost no signs of ditching were observed. This is in accordance with van Dijken (11) and van Dijken & Hørstedt (12), who observed good marginal integrity by clinical and SEM observations after 6 and 5 years, respectively, for direct composite resin inlays.

Generally, inlays produced indirectly have been reported to be less accurate than directly produced inlays (21). This was explained by the more complex process of manufacturing. Nevertheless, this factor did not seem to influence noticeably marginal leakage in the present study, as marginal discoloration was rare.

The anatomic form was usually rated "Alfa", but in a few cases the proximal contact was inadequate and rated "Bravo", probably not due to wear, but to improper restoration contour.

The replica method revealed small defects in the occlusal surfaces of a few inlays. These defects might be tiny air-bubbles entrapped during the production of the inlays, or perhaps a beginning process of degradation. Later evaluations may give information about this.

No secondary caries was found around the inlays. This is in accordance with observations by Krejci et al. (22) and Wassel et al. (10), who followed inlays/onlays for 1 and 5 years, respectively. In another study, where almost half of the patients were considered to be at high caries risk, secondary caries was found around only 2% of the inlays after 6 years of service (11). After 8 years, however, Pallesen & Qvist (13) reported that secondary caries was the most frequent reason (4.4%) for replacement of indirect inlays. In the present study a few of the gingival cavity margins (about 15%) were located in dentine, but so far this does not seem to have influenced susceptibility to recurrent caries.

One onlay covering the buccal, mesial, and occlusal surfaces of a lower molar fractured. This might be related to masticatory stress, or internal faults of the inlay caused by the incremental build-up technique. It may be of interest to note that a significantly higher success rate for adhesive inlays has been reported for premolars than for molars (23). A failure rate of 2% (Table 4) in the present study is in accordance with Pallesen & Qvist (24), who reported a replacement frequency of 2.1% for indirect composite resin inlays after 2 years of service. In comparison, the composite resin fillings in saucer-shaped cavities showed a replacement frequency of 18% and 31% after 3 and 10 years of service, respectively (15).

In accordance with van Dijken (11), the present study showed that the composite resin inlays have a better performance than the direct composite resin fillings. After an evaluation period of 20 ± 8 months, the results are promising. At the first evaluation of this longitudinal study, no differences in the performance could be found between inlays and onlays, neither between premolars nor molars.

This treatment modality seems indicated in medium-sized MOD cavities. Many of the problems associated with direct placement composite resin restorations seem to be overcome by the inlay technique, although the procedure remains technique sensitive (2). Other problems do arise, however, particularly related to the luting procedure. The method is time-consuming and therefore expensive (9). Deficiencies observed were mostly technique-related, and this stresses the importance of accuracy. A continuing follow-up of this study may reveal further details of the suitability of the method.

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Received for publication 11 March 1999
Accepted 28 June 1999