Clinical evaluation of glass ceramic inlays (Dicor)

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The purpose of the study was to evaluate the clinical behavior of ceramic class-II inlays (Dicor) in the first 2 years after placement. As a reference, a similar number of dental amalgam restorations were followed up during the same period. Twenty-five inlays and 25 dental amalgams were placed on premolars and first molars of 20 and 19 patients (15–19 years old), respectively. The inlay preparations were made in accordance with the manufacturer's recommendations, and the inlays were produced by a licenced Dicor laboratory. The inlays were luted, using a glass ionomer cement. The dental amalgam preparations were made using standard class-II preparation techniques and filled with ANA 2000. The inlays were evaluated after 6, 12, and 24 months, and the dental amalgam restorations after 24 months, using the criteria suggested by Ryge. In addition, the 24-month examination included proximal recording of dental plaque and gingivitis. With the exception of two inlays that fractured during the observation period, all ceramic inlays showed excellent ratings for anatomic form, marginal discoloration, and marginal caries at all examinations. Two inlays showed minor marginal defects but were classified within the range of acceptance with no need for replacement. The two fractured inlays were replacements of earlier fractured dental amalgams. The clinical behavior of the dental amalgam restorations was in most respects similar to that of the ceramic inlays. Unlike the inlays, however, no dental amalgams fractured during the observation period. No significant differences in the amount of dental plaque or the degree of gingival inflammation were noted between the ceramic inlays and their contralateral control surfaces or between the ceramic inlays and the reference material of dental amalgam restorations.
☐ *Dental amalgam; dental ceramics; dental materials*

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In recent years there have been increasing demands for alternatives to dental amalgam for posterior restorations. So far, interest has mainly focused on composite resins and glass ionomer cements, but ceramic materials have also attracted attention. Ceramic materials have excellent aesthetic qualities and are reported to be bioinert, to have a hardness similar to that of enamel, and to undergo only small volume changes, which should favor good adaptation to the cavity walls (1, 2). In addition, the plaque retention potential is reported to be lower than that of enamel (3). On the other hand, the dental ceramics are fracture-sensitive (4), and there is concern that abrasion of teeth opposed by ceramic materials may lead to loss of enamel (5).

In an evaluation of the clinical quality of ceramic inlays (Dicor) placed by general practitioners, Bessing & Molin (6) reported that 54% of the inlays showed slight color mismatch, 14% roughened surface, and 30% visible evidence of ditching along the margins. The mean age of the inlays at the evaluation was 11 months (range, 1–22 months). In a prospective, clinical study Cavel et al. (7) reported that color match and marginal adaptation of the ceramic inlays (Dicor) were very favorable, with no evidence of cavosurface margin discoloration or caries at the 6-month follow-up.

As indicated above, dental ceramics are a promising alternative for posterior restorations, with physical and chemical properties that in many respects are superior to those of composite resins and glass ionomer cements. More clinical tests are needed, however, and controlled studies over longer periods are scarce. Therefore, the aim of the present study was to evaluate the clinical behavior of ceramic class-II inlays (Dicor)

during a 2-year period after placement. As reference, a similar number of dental amalgam restorations were followed up during the same period of time.

Materials and methods

Study groups

Fifteen- to 19-year old patients, in need of one or more class-II restorations in premolars or first permanent molars, were selected for the study. Patients with anamnestic information about parafunctional habits (tooth grinding, tooth clenching) were excluded. One group of patients received ceramic inlays and the others the standard dental amalgam treatment.

Twenty-five ceramic inlays (Dicor, DeTray Dentsply, Dreieich, Germany) and 25 dental amalgam restorations (ANA 2000, Nordiska Dental AB, Helsingborg, Sweden) were placed in 20 and 19 patients, respectively. All but two restorations in the inlay group and all but four in the dental amalgam group were occasioned by primary proximal caries. The other restorations were replacements of defective dental amalgam or glass ionomer cement restorations. The caries lesions were all confined to the proximal surface, and no caries lesion extended to the buccal, lingual, or occlusal surfaces. The distribution of restorations by type of tooth is given in Table 1. One inlay included both proximal surfaces. The remaining inlays and all dental amalgams consisted of two-surface restorations. One patient received 3 inlays, 3 patients 2 inlays, and 16 patients 1 inlay. In the dental amalgam group, 1 patient received 3 restorations, 4 patients 2 restorations, and 14 patients 1 restoration.

Clinical procedures

All the patients were treated by one of the authors (R. Stenberg). The inlay preparations were made in accordance with the manufacturer's recommendations, based on the concept of a standard class-II preparation. All internal angles were rounded, undercuts were avoided as far as possible, and a minimum occlusal reduction of 1.5 mm was made. In addition, no cavosurface bevels were made, and the walls of the preparations were slightly flared and prepared to meet the tooth surface at or near a right angle. All cavity margins were located in the enamel. After the preparation the operation field was kept dry, using cotton rolls and a saliva suction equipment. No rubber dam was used.

Dentinal areas in close proximity to the dental pulp were blocked with a calcium hydroxide base (Dycal, L.D. Caulk Co., Milford, Del., USA). When base was needed, only isolated spots of base were applied. Undercuts were blocked out with glass ionomer cement (Chemfill, DeTray Dentsply) before the impression was made. When needed, the gingiva was retracted with retraction cord (Ultrapak, Ultradent Products Inc., Salt Lake City, USA). A full-arch impression was taken, using an irreversible hydrocolloid impression material (Vocolloid, VocoChemie, Cuxhaven, Germany). An alginate impression (Alginoplast, Bayer Dental, Leverkusen, Germany) of the opposing jaw was also taken. The cavity was then furnished with a light-cured temporary restoration (Barricade, L.D. Caulk Co.).

The inlays were manufactured by a

Table 1. Number of restorations placed

	Upper jaw		Lower jaw	
	Premolars	1st molars	Premolars	1st molars
Ceramic inlays ($n = 25$)	10	6	5	4
Dental amalgams ($n = 25$)	5	8	6	6

licensed Dicor laboratory. At the laboratory the inlays were etched, but no coupling agent was applied.

During the removal of the temporary restoration and the following placement of the inlay, the operation field was kept meticulously dry. The inlays were cemented with glass ionomer cement (Fuji I, G-C Dental Industr. Co., Japan). The excess cement was removed with a carver after setting, and occlusal adjustments were performed, if needed, followed by polishing.

The extension of the cavity preparations for the dental amalgam restorations was similar to that of the inlays. All internal angles were rounded. Cavity liner (Tubulitec, Dental Terapeutics AB, Nacka, Sweden) was applied, and in the case of close proximity to the dental pulp the dentinal areas were blocked with a calcium hydroxide base (Dycal, L.D. Caulk Co.).

Evaluation

Approximately 2 weeks after placement of an inlay the patient was contacted by telephone, and questions were asked about postoperative discomfort (pain, hypersensitivity, occlusal interferences, and so forth).

Immediately after placement of the restorations and after 6, 12, and 24 months (inlays) and 24 months (dental amalgam restorations), a clinical evaluation of the restorations was performed using the criteria suggested by Ryge (8). The following properties were included in the evaluation: marginal adaptation, anatomic form, marginal discoloration, caries adjacent to the restoration, and color match. The rating system has specific criteria for each property, and the restorations are rated into two main categories: satisfactory versus not acceptable, with two subratings within each category:

Satisfactory
- Alfa (no changes or clinical remarks)
- Bravo (minor defects, no need for replacement)

Not acceptable
- Charlie and Delta (need for replacement)

In addition, at the 24-month examination the amount of dental plaque (9) and the

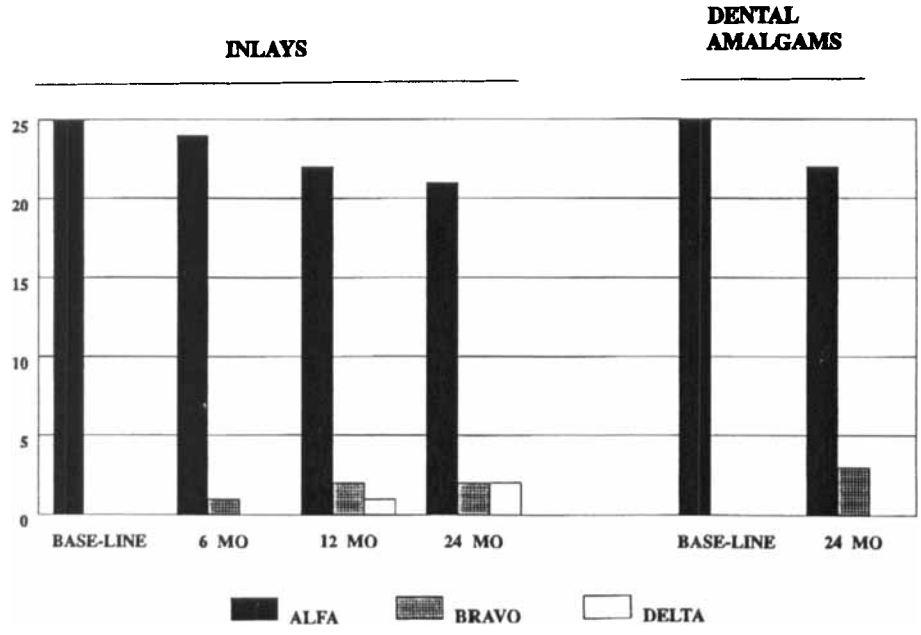

Fig. 1. Marginal adaptation. Number of ceramic inlays and dental amalgam restorations classified in groups on the basis of clinical performance (22). ALFA = no clinical remarks; BRAVO = minor defects, no need for replacement; DELTA = fracture, need for replacement.

gingival state (10) were assessed at the proximal surface of the restoration and at a contralateral tooth surface.

All base-line evaluations were performed by one of the authors (R. Stenberg). The evaluations of the restorations after 6, 12, and 24 months were done simultaneously by both authors, while the recording of plaque and gingivitis was performed by Stenberg.

The amount of dental plaque and the gingival state were compared, using Fisher's exact test. Differences at the 5% level of probability were considered statistically significant.

Results

Ceramic inlays

None of the patients reported postoperative discomfort or any subjective symptoms during the follow-up period. No clinical signs of enamel wear due to abrasion were noted on teeth opposing ceramic inlays.

Fig. 1 shows the evaluation of marginal adaptation during the period. At the 24-month examination 21 inlays were rated Alfa (no clinical remarks), 2 Bravo (marginal crevice), and 2 Delta. One of the Delta-rated inlays had fractured between the 6-month and 12-month recalls, and the other between the 12-month and 24-month recalls. Both fractured inlays were replacements of fractured dental amalgam restorations. One inlay had fractured in the isthmus region, the other in the proximal contact area. These inlays were replaced by composite restorations.

The anatomic form of the 23 non-fractured inlays was rated Alfa at all examinations during the period. There was no evidence of marginal discoloration or marginal caries in any of the inlays. With regard to color match, 17 inlays were rated Alfa at base line and 8 Bravo (slight mismatch in color between enamel and inlay). No changes in color match were seen during the 2-year period.

Dental amalgam restorations

In the evaluation of marginal adaptation at the examination after 24 months (Fig. 1), 22 dental amalgams were rated Alfa and 3 Bravo. Anatomic form was rated Alfa in all restorations. Two restorations, both found in the same patient, showed marginal caries at the 24-month recall and thus needed to be repaired.

Dental plaque and gingivitis

No statistically significant differences in the amount of dental plaque (Table 2) or the degree of gingivitis (Table 3) were found between the ceramic inlays and their contralateral control surfaces or between the dental amalgam restorations and their contralateral controls at the 24-month examination. Nor were any statistically significant differences noted between the ceramic inlays and the dental amalgam restorations.

Table 2. Distribution of proximal surfaces with ceramic inlays or dental amalgam restorations and contralateral control surfaces among plaque index classes. Evaluation after 24 months

	Plaque index					
	0		1		2	
	n	%	*n*	%	*n*	%
Ceramic inlays ($n = 23$*)	6	26.1	14	60.9	3	13.0
Controls ($n = 25$)	3	12.5	17	70.8	4	16.7
Dental amalgams ($n = 25$)	2	8.0	17	68.0	6	24.0
Controls ($n = 25$)	0	0.0	20	80.0	5	20.0

* Two inlays fractured during the observation period.

Table 3. Distribution of proximal surfaces with ceramic inlays or dental amalgam restorations and contralateral control surfaces among gingival index classes. Evaluation after 24 months

	Gingival index					
	0		1		2	
	n	%	*n*	%	*n*	%
Ceramic inlays ($n = 23$*)	4	17.4	7	30.4	12	52.2
Controls ($n = 25$)	4	16.7	3	12.5	17	70.8
Dental amalgams ($n = 25$)	1	4.0	7	28.0	17	68.0
Controls ($n = 25$)	0	0.0	9	36.0	16	64.0

* Two inlays fractured during the observation period.

Discussion

With the exception of two inlays that fractured during the observation period, all ceramic inlays showed excellent ratings for anatomic form, marginal discoloration, and marginal caries at all examinations. Two inlays showed minor marginal defects but were classified within the range of acceptance, with no need for replacement.

It is notable that both fractured inlays replaced fractured dental amalgam restorations. These were the only inlays made for this reason, the other 23 being occasioned by primary proximal caries. Patients with clinical signs of parafunctional habits were not included in the study, but possibly, the repeated fractures indicate that these teeth were exposed to exceptional bite forces and should accordingly not have been subjected to inlay treatment. Concern has been expressed about a high fracture sensitivity of ceramic materials, and variations in this respect have been reported between different ceramic materials (4, 11, 12).

The favorable clinical performance of the 23 inlays placed in teeth exposed to normal stress is in line with the results from earlier studies of castable ceramic inlays (6, 7). However, whereas Cavel et al. (7) reported excellent results from their clinical evaluation in all respects, Bessing & Molin (6) in their retrospective study found marginal defects in 30% of the inlays and, in a substantial number, some divergence in anatomic form and color match. However, all but one (fractured) inlay were classified as acceptable, in accordance with the results from the present study. Sjögren et al. (13), in a recently published study using the same study design and the same criteria for evaluation as Bessing & Molin (6), reported similar or, in some respects, better clinical performance of CAD-CAM produced ceramic inlays (Cerec).

Our results are also in accordance with those from a recently published experimental study by Krejci et al. (14), evaluating the performance of 10 ceramic inlays (IPS/Empress), seated with a dual-curing composite resin cement, over 1.5 years. The clinical evaluation showed excellent ratings of wear, marginal integrity, color match, marginal discoloration, and marginal caries. However, scanning electron microscopy (SEM) examination showed signs of marginal breakdown, and it is conceivable that the long-term performance of the inlay margins is uncertain.

In one-third of our inlays a slight color mismatch was seen between enamel and inlay. This was noted already at the baseline examination. All these inlays were rated Bravo—that is, within the normal range of tooth shades—and the mismatch was generally only observable under operation lighting. As no changes in color match were seen during the observation period, the color stability of the material seems to be good.

According to the manufacturer's recommendations, the Dicor inlays may be luted either with composite resin in com-

bination with etching and silanization, or with glass ionomer cement. Both techniques have their advantages and drawbacks, but in view of the high sensitivity of the adhesive technique, with a considerable risk of errors by the dentist, we used a glass ionomer cement in our study. This technique has fewer operative steps and was considered easier to master when seating the present very small inlays. There are, however, reports of higher risks of microleakage when ceramic crowns are luted with glass ionomer cement compared with composite resin cement (15), and recently Höglund et al. (16), in a clinical evaluation of ceramic inlays/onlays seated with dual-cured composite resin cement or glass ionomer cement, reported a higher failure rate in the glass ionomer cement group. The failures in the latter study were in most cases caused by adhesive fractures at the interface between cement and inlay. On the other hand, the report from the SEM analysis by Krejci et al. (14) of a gradual wear of the composite cement used in their study deserves attention, and long-term studies are needed before any conclusions concerning the use of different luting cement can be drawn.

Earlier studies report occasional cases of hypersensitivity after placement of ceramic inlays. The discomfort is reported to be slight and temporary. None of our patients reported any symptoms at the 2-week check-up or during the follow-up period. Thus, in ceramic restorations luted with glass ionomer cement and of limited dimension, like inlays of the present type, postoperative hypersensitivity seems to be an insignificant problem.

No significant differences in the amount of dental plaque or the degree of gingival inflammation were noted between the ceramic inlays and the contralateral control surfaces or between the ceramic inlays and the reference material of dental amalgam restorations. Earlier studies have reported a lower (3, 6) or similar (13) degree of plaque accumulation on ceramic inlays. Thus, it seems that the plaque adherence capacity of glass ceramics is at least not higher than that of dental enamel or dental amalgam restorations.

As a reference, a simlar number of dental amalgam restorations was placed on a group of patients of the same age as those who received inlays, applying the same criteria for inclusion in the study. The clinical behavior of the dental amalgam restorations was in the most respects similar to to that of the ceramic inlays. Unlike the inlays, however, no dental amalgams fractured during the observation period. On the other hand, two dental amalgams needed to be repaired owing to marginal caries, detected at the 24-month recall. Both these amalgams were found in the same patient, a girl who had moved from home and came back at the 24-month recall, presenting an overall high caries activity.

In conclusion, the ceramic inlays tested (Dicor) performed well during the 2-year observation period. This type of material therefore seems to be a promising alternative to other tooth-colored materials for use in stress-bearing areas of the mouth. However, the high fracture sensitivity of the material, represented here by the fracturing of 2 of the 25 inlays during the test period, calls for caution in the case of teeth exposed to exceptional bite forces. Also, long-term studies are needed before any safe conclusions about the clinical performance of class-II ceramic inlays can be drawn.

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