A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings

A 6-year follow-up study

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Dijken JWV van. A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings. A 6-year follow-up study. Acta Odontol Scand 1986;44:357–367. Oslo. ISSN 0001-6357.

Anterior resin fillings of seven composite resin materials—two conventional, two hybrid, and three microfiller—were evaluated over a 6-year period. Extrinsic discoloration, color match, marginal discoloration, marginal adaptation, surface roughness, and recurrent caries were investigated. The individual caries increment was compared with an estimation of the expected caries risk of the individuals. The estimation was based on the net effect of microbial counts, oral hygiene, salivary flow rates, buffer values, and fermentable carbohydrate intake. The variation of the investigated factors within each resin group was too great to enable combination of the results. The individual materials are therefore presented and compared. Unacceptable color match scores after 6 years varied markedly among the brands (3.5%–79.7%). Unacceptable marginal discoloration was seen in 1.7% of the restorations, whereas unacceptable marginal adaptation varied between 13.7% and 37.3% for the brands. Recurrent caries occurred at the margins of 18.9% of the composite fillings (range, 9.3%–29.4%) during the period. The cumulative relative frequencies of replaced fillings for the materials varied between 14.8% and 55.1%. Recurrent caries was the major reason for replacement. Patients with many caries risk factors showed clearly a higher increment of caries. □ *Cariology; color match; discoloration; marginal adaptation; operative treatment; recurrent caries; surface roughness*

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On the basis of the average particle size, three types of composite resins can be recognized—conventional, microfiller, and hybrid (1). Conventional composite resins contain filler particles in the range of 1–100 μm. Within this group some products have filler particles mainly in the range of 1–6 μm. Others have particles chiefly between 15 and 20 μm but with some large particles up to 50 or even 100 μm. Although these resins showed improved clinical performance over the unfilled resins and silicate cements, they still gave rise to problems related to surface roughness and color instability.

Microfiller resin systems were introduced in 1976. They contain pyrolitic silica fillers of approximately 0.04 μm and can be finished to smooth surface characteristics (1). Compared with the conventional composites, their low inorganic filler proportion resulted in higher water sorption, higher modulus of elasticity, and higher linear coefficient of thermal expansion (2).

In an attempt to maintain the advantages of both conventional and microfiller resins, hybrid composite resins became available from 1979. They contain a blend of microfiller particles and a major amount of glass fillers in the range of 1–15 μm. The physical properties of these resins have been well reviewed (3). Although the clinical performance of the new composite resins has been investigated by direct visual examination of changes in clinical characteristics like color match, marginal adaptation, marginal discoloration, and surface roughness (3–8), most studies have had a duration of 3 years or less. No long-term study is available comparing the three resin types. Hence it is not clear whether the new composite resins improve the durability of anterior resin restorations. The aim of the present exper-

imental study was to evaluate the clinical quality and durability of brands of each of the three composite resin types in anterior cavities during a 6-year period.

Materials and methods

The investigation was based on 303 anterior restorations placed in 27 patients with relatively high caries experience (mean DMFS, 79; range, 54–114). The patients ranged in age from 22 to 65 years (mean, 42.2). The investigated materials, their characteristics, and the number and distribution of class III, IV, and V restorations are listed in Table 1. Each patient received at least one filling of each of the three composite resin types. Each material was mixed and handled in accordance with the manufacturers' instructions. The cavity margins were bevelled, whereas the unsupported enamel at the nonbevelled margins, mostly gingival margins, was removed with finishing burs at low speed. The cavities were then thoroughly isolated with cotton rolls and a saliva suction equipment, dried by air blast, and cleaned with a surface-active cavity cleanser (Tubiulicid-blue, Dental Therapeutics Ltd., Ektorp, Sweden). When a dry operation field could not be obtained because of subgingivally located cavity margins, the margins were exposed electrosurgically. No rubberdam was used. A layer of calcium hydroxide base (Dycal, L. D. Caulk Co., Milford, Del., USA) was applied before the acid etching of the enamel cavity margins. The etching was made for 60 sec with 37% phosphoric acid. After thorough spraying with water (20 sec) and drying with compressed air, the composite resin was inserted. No intermediate low-viscosity resin was used. Mylar matrix strips and crown forms were used for class III and class IV restorations, respectively, and a cervical metal matrix (Hawe, Neos Dental, Gentelino, Switzerland) for class V restorations. The fillings were finished after 1 week. Conventional and hybrid composite resins were finished with an Arkansas stone (Amalgamated Dental Co., London, U.K.) and with polishing strips (3M Dental Products, St. Paul, Minn., USA) as the last step.

Table 1. Restorative materials investigated

Material	(code)	No. of fillings of class III	IV	V	Characteristics	Filler particle	Filler dimension	Manufacturer
Adaptic	(A)	29	4	9	Two-paste conventional composite resin	Quartz	1–40 µm	Johnson & Johnson Ltd, New Brunswick, N.Y., USA
Profile	(P)	14	2	9	Two-paste conventional composite resin	Strontium glass	8 µm	S.S. White Dental Products, St. Paul, Minn., USA
Silar	(S)	28	10	17	Two-paste microfiller composite resin	SiO_2 (pyrogenic)	0.04 µm	3M Dental Products. St. Paul, Minn., USA
Isopast	(I)	20	2	7	Two-paste microfiller resin	SiO_2 (pyrogenic)	0.04 µm	Vivadent, Schaan, Liechtenstein
Durafill	(DU)	28	9	9	One-paste microfiller composite resin	SiO_2 (pyrogenic)	0.04 µm	Kulzer & Co., Bad Homburg GmbH, FRG
Miradapt	(M)	17	4	12	Two-paste hybrid composite resin	Barium glass + SiO_2 (pyrogenic)	12 µm 0.04 µm	Johnson & Johnson Ltd, New Brunswick, N.Y., USA
DRS	(D)	47	8	17	Two-paste hybrid composite resin	Glass + SiO_2 (pyrogenic)	1–40 µm 0.04 µm	Coltène Inc., Alstätter, Switzerland

The microfiller resins were finished with the Soflex system (3M Dental Products), followed by a fine polishing paste (Jodka Fluor, Jod-Kaliklora-fabriken, Gothenburg, Sweden) in a rubber cup. All fillings were placed and finished by me.

Evaluation

Each restoration was evaluated by me with regard to extrinsic discoloration, color match (intrinsic discoloration), marginal discoloration, marginal adaptation, surface roughness, and the presence and location of recurrent caries, using a slight modification of the U.S. Public Health Service technique developed by Cvar & Ryge (9). The criteria are listed in Table 2. The restorations were polished before evaluation of color match and refinished if assigned surface roughness score 3. Base-line determinations were made 1 week after placement, and the restorations were evaluated again every 6 months during the 6-year period. In addition, color slides were taken routinely, and these were used at the end of the study to verify the evaluation scores. The assessments of each test restoration were made without availability of earlier assessments or knowledge of the material used for each restoration.

The reproducibility of the examiner evaluation was tested on the basis of independent double examinations made at 2-week intervals on three occasions before and during the study period.

Expected caries activity

Caries was also registered for the nonexperimental tooth surfaces. A prediction of the caries risk, expressed as the potential caries activity, was made for all patients. The prediction was compared with the actual caries development in each patient. Details of the procedure used to analyze the expected caries activity for the individual patient have been presented earlier (10; J. W. V. van Dijken, H. Forsberg, T. Ericson, H. Kollberg. Caries increments and risk evaluation in children with cystic fibrosis. Unpublished observations).

The potential caries activity is defined by the caries risk estimated from the net effect of oral hygiene, intake of fermentable carbohydrates, salivary microbial counts, salivary flow rates, and buffer values. These factors were recorded three times during the study period and were regarded as negative factors favoring caries development when certain values were exceeded.

Oral hygiene was defined as a negative factor when a plaque score (11) of more than 2 or gingival bleeding (12) on more than 30% of the tooth surfaces was recorded on more than one occasion. Intake of fermentable carbohydrates a mean of six times a day or more registered during 4 days (13) was regarded as a negative factor. The presence of more than 5×10^5 CFU/ml saliva of *Streptococcus mutans* (14) (CFU = colony-forming units) or 10^5 CFM/ml saliva of lactobacilli (15) on more than one occasion was regarded as a negative factor, as were a buffer pH value (16) of 5.3 or lower and a flow rate of 0.75 ml/min or less (10). Samples of stimulated whole saliva (5 ml) were collected, between 0800 h and 0900 h, into ice-chilled tubes by chewing on 0.5 g paraffin. For each individual a maximum of six negative factors could thus be obtained. The relationship between the number of negative factors and caries development was evaluated.

Statistical analysis

To eliminate the effects of an uneven representation of materials among the fillings in each patient, the number of fillings of each material with a given index score was normalized to the total number of fillings with that material in the particular patient. For example, out of four fillings made of one material placed in a patient, two (50% of these fillings) may have score 0 for a particular factor, one (25%) may have score 1, and one (25%) may have score 3. The relative frequencies of the scores for this factor of all the patients who had received fillings of the material were then calculated, and the mean values of these relative frequencies present descriptively the scores of the factor in the figures.

The relative frequencies (%) of the scores

Table 2. Criteria for clinical evaluation

Category	Score (acceptable/unacceptable)		Criteria
Color match	0		Very good color match, restoration almost invisible.
	1		Good color match.
	2		Slight mismatch in color, shade or translucency.
		3	Obvious mismatch, outside the normal range.
		4	Gross mismatch.
Marginal discoloration	0		No discoloration evident
	1		Slight staining, can be polished away.
	2		Obvious staining, cannot be polished away.
		3	Gross staining.
Marginal adaptation	0		Restoration is continuous with existing anatomical form; explorer does not catch.
	1		Explorer catches, no crevice is visible into which explorer will penetrate.
	2		Crevice at margin, enamel exposed.
		3	Obvious crevice at margin, dentin or base exposed.
		4	Restoration mobile, fractured or missing.
Surface roughness	0		Smooth surface.
	1		Slightly rough or pitted.
	2		Rough, cannot be refinished.
		3	Surface deeply pitted, irregular grooves.
Caries	0		No evidence of caries contiguous with the margin of the restoration.
		1	Caries is evident contiguous with the margin of the restoration.

for each of the materials within each patient were then compared and ranked. In this manner each patient served as a statistical unit (one degree of freedom). The variation of the investigated factors within each resin group was large. The individual materials were therefore compared, instead of the three resin types. Because not all the brands were represented in each patient, two materials were compared at a time at the ordinal level, using the sign test (17).

Results

All patients returned for examinations every 6 months during the 6 years of the study. The examinations repeated at 2-week intervals showed good reproducibility by the examiner. Ninety-one per cent of the observations were assigned the same score on both occasions.

Except for recurrent caries and loss of retention (marginal adaptation score 4), the evaluated clinical characteristics showed no obvious differences for the materials in relation to location of the fillings. The few class IV and V fillings were therefore added to the class III fillings and were described and tested together.

Clinical assessments

Extrinsic discoloration. Thirty per cent of the patients (all smokers) showed extrinsic staining of the restorations during the evaluation period. The stain could easily be polished off. Several of these patients had no stain on the labial surfaces but did have stain on the proximal and lingual surfaces. No significant differences in extrinsic staining was detected between the different materials.

Color match (intrinsic discoloration). The relative distributions of surfaces with acceptable color match scores (0–2) at year 6 are shown in Fig. 1. At year 6 the conventional resins (A, P) showed significantly more

acceptable color match scores than one of the hybrid resins (D; $p < 0.001$) and the chemically cured microfiller resins (I; $p < 0.01$; S; $p < 0.05$). The other hybrid resin (M) showed better color match than the chemically cured microfiller resins ($p < 0.05$). The number of statistical units in the comparisons between M and D and between DU and D, S, or I was too low to make adequate statistical testing possible. Therefore no significant differences could be shown between these materials, as expected from the descriptive results in the figures. No significant differences were found in the other comparisons. The loss of color match of the resins during the 6 years is shown for each material in Fig. 2. It is expressed as the cumulative relative frequencies of surfaces with unacceptable color match scores (3 and 4; cf Table 2) at each control visit. The two chemically cured microfiller resins (I, S) and one hybrid composite resin (D) showed a faster and more severe color change during the evaluation period than the other materials. The patients often accepted a degree of discoloration which the dentist thought excessive. After discussion with the patients only 17 (5.7%) restorations were replaced because of severe color change during the course of the study.

Marginal discoloration. The acid-etched cavities were not particularly prone to develop cavomarginal discoloration within the first 3 years after placement (score 2 and 3, 2.7%). At year 6 the distribution was slightly higher (score 2, 7.3%; score 3, 1.7%). There were no significant differences between the materials. No fillings were replaced because of marginal discoloration, but it was frequently found in combination with recurrent caries. In all cases recurrent caries was the main reason for replacement.

Marginal adaptation. The cumulative relative frequencies of surfaces with unacceptable marginal adaptation scores (3 and 4) for the different composite resins during the 6 years are given in Fig. 3. The conventional resins (A, P) showed significantly better adaptation than one of the hybrid resins (D, $p < 0.01$) and the chemically cured microfiller resins (I, $p < 0.01$; S, $p < 0.05$). The other hybrid resin (M) showed better

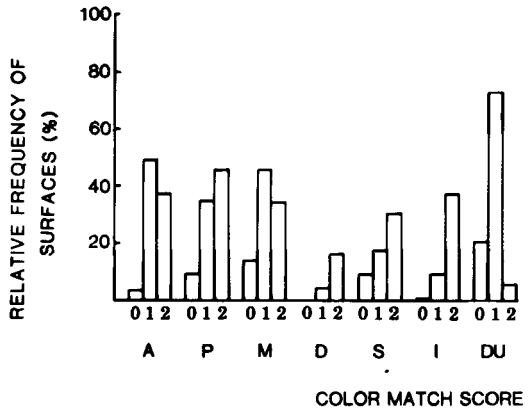

Fig. 1. Relative frequency (%) of composite restorations with acceptable (score 0–2) color match at the 6-year control visit. For symbols, see Table 1.

adaptation than the chemically cured resins ($p < 0.05$). M could not be tested adequately against D, nor could DU against D, S, and I, because of the low number of patients who received fillings of both materials.

Loss of retention (score 4) occurred in 1.1% of the class-III fillings and in 25% of the class-IV fillings. Sixty-seven per cent of the losses occurred before 30 months of service. Seventy-five per cent of the class-IV retention failures occurred in patients

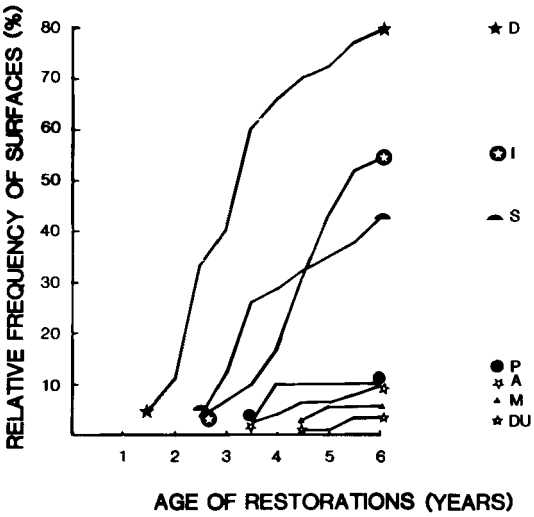

Fig. 2. Degradation of color match. Cumulative relative frequencies (%) of composite restorations with unacceptable color match (scores 3 and 4) during the 6-year period.

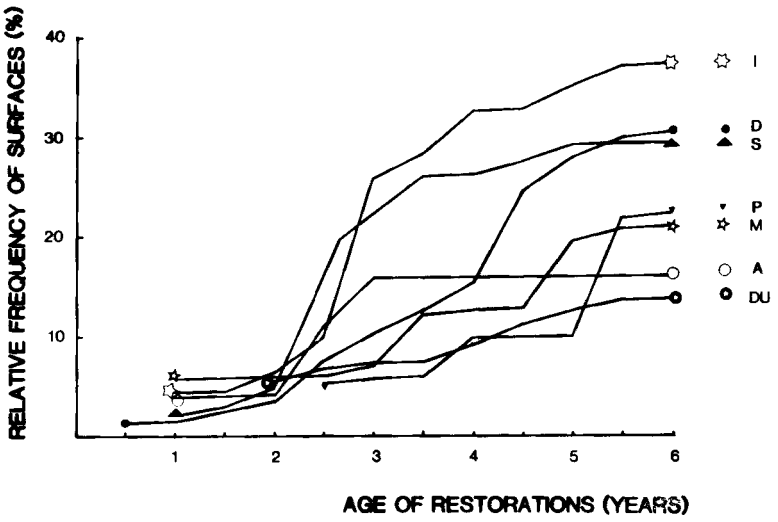

Fig. 3. Degradation of marginal adaptation. Cumulative relative frequencies (%) of composite fillings with unacceptable marginal adaptation (score 3 and 4) during the 6-year period.

with bruxism. Replacements of these restorations, placed in combination with the intermediate resin recommended by the manufacturers, failed in all cases a second time, and in 37.5% even a third time. Lack of acceptable marginal adaptation was the main reason for replacement in 8% of the fillings (score 3, 4%; score 4, 4%). In all cases in which marginal adaptation failure was combined with recurrent caries, the decay was registered as the main reason for replacement.

Surface roughness. The conventional quartz filler-loaded resin (A) showed the roughest surfaces during the study, whereas the smoothest surface characteristics were seen for the microfiller resins. At the 6-year registration there was a significant difference ($p < 0.001$) in surface characteristics between the following groups of materials, ranked from rough to smooth: A; M and D; P; S; I and Du. Deeply pitted, irregular surface characteristics (score 3) were observed in 1.7% of the restorations.

Caries. The cumulative relative frequencies (%) of recurrent caries contiguous with

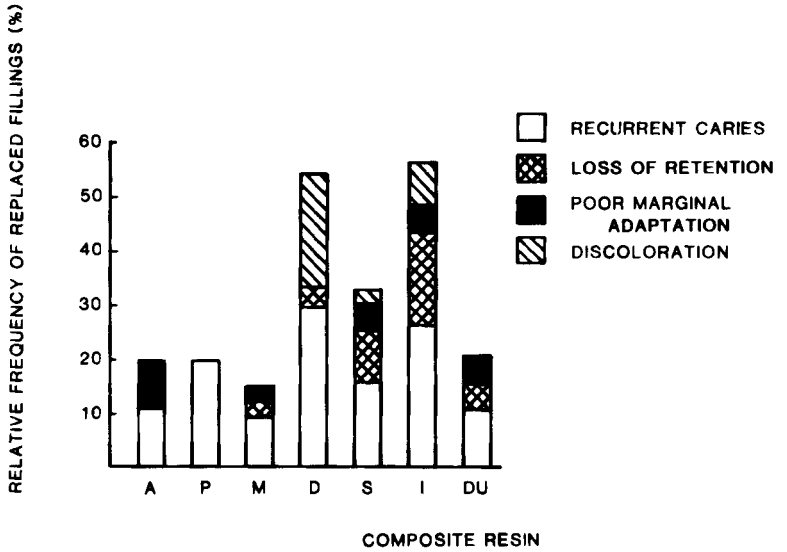

Fig. 4. Relative frequencies (%) of replaced fillings during the 6-year period and the reason for replacement for each filling material.

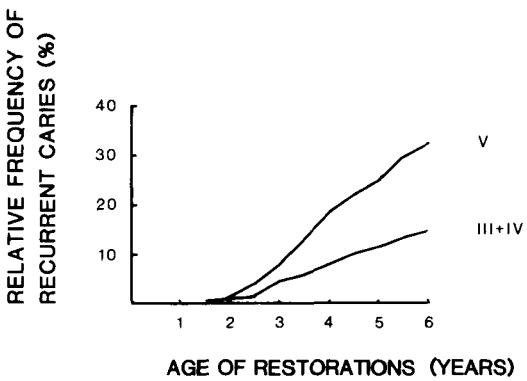

Fig. 5. Cumulative frequencies (%) of recurrent caries contiguous with class V and class III and IV composite resin restorations during the 6-year period.

different composite materials are shown in Fig. 4. The cumulative frequencies of recurrent caries contiguous with composite resin restorations varied among the different restoration classes (Fig. 5). The few class-IV fillings were added to the class-III fillings. Almost all recurrent carious lesions (96.5%) were detected at the cervical cavity margins of the restorations.

Of the recurrent lesions contiguous with class-V composite resin margins, 46% were registered as root caries, whereas 3.1% of the recurrent caries lesions contiguous with proximal fillings were registered as root surface caries. The other lesions were localized only at the margins of the restorations.

Of the composite surfaces 18.9% showed recurrent caries during the 6-year period, whereas 8.6% of the amalgam surfaces, which were in situ and judged as acceptable at the start of the study, showed recurrent caries. Primary carious lesions were detected on 3.1% of the unfilled surfaces.

Replacement of restorations

The cumulative relative frequencies (%) of replaced restorations for the investigated materials during the study period are shown in Fig. 6. Two materials (D, I) showed a clearly higher replacement frequency than the other materials. The reasons for replacement are shown in Fig. 4. Recurrent caries was seen as the main reason.

Expected caries activity

The relationship between the number of negative factors and the relative frequency of

Fig. 6. Cumulative relative frequencies (%) of replaced restorations during the 6-year period.

recurrent caries contiguous with composite restorations and the total caries increment (primary and recurrent caries lesions) are shown in Figs. 7 and 8, respectively. Caries increment is given as the mean of the relative frequencies of carious lesions of the patients and compared with the respective number of negative factors. None of the patients had a total of four or six negative factors. The seven patients with three or more negative factors showed twice as many carious lesions as patients with 0–2 negative factors.

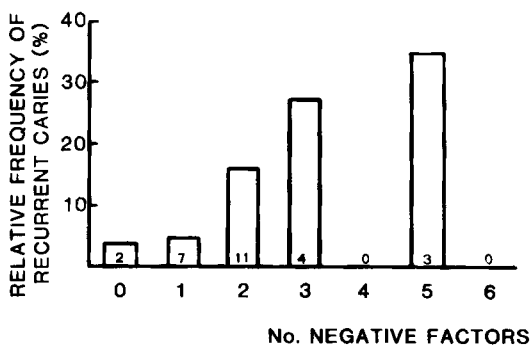

Fig. 8. Relative frequencies (%) of caries increments (primary and recurrent) versus number of negative factors of the patients. See also legend to Fig. 7.

Discussion

From the present study it is clear that the color change is time-dependent and varies among the materials. The large variation among the materials must be kept in mind when evaluating color stability. Of the hybrid resins, one (D) was judged to have a clinically unacceptable color mismatch already after 3 years, whereas the other resin (M) showed good color stability throughout the 6-year period. In the microfiller group one of the chemically cured resins (I) was judged as not acceptable after 4–5 years, whereas another microfiller material (DU), together with the two conventional composites, showed stable color-match characteristics. It is clear that evaluation periods longer than 3 years are required for evaluation of clinical color stability of chemically cured resins.

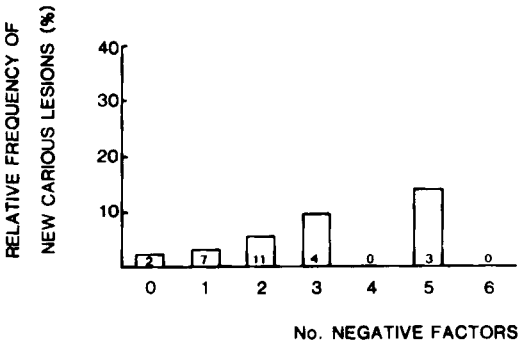

Fig. 7. Relative frequencies (%) of recurrent caries contiguous with composite resin restorations versus the number of negative factors of the patients. The bars represent the mean number of the relative frequencies of lesions of the patients with the respective number of negative factors. The number of patients in each group is given in the bars.

It has been suggested that extrinsic staining of composite resins is not a major problem after the introduction of the microfiller resins because they have smooth surface characteristics (5). There was, however, no difference in accumulation of stain among the tested microfiller and conventional and hybrid resins. The findings in this study confirm the results of Roulet-Mehrens & Roulet (18) that there is no correlation between surface roughness and smoke stain.

A marked increase in deterioration of the marginal adaptation of the fillings after the 3rd year of clinical service was observed in this study. The materials that showed greatest color match failures also showed the highest adaptation failures (D, I, S). At the start of this study (1979) opinions about the need for an intermediate bonding agent were controversial. Resin tag formation was not enhanced, nor was the enamel bond strength improved by the use of an intermediate bonding agent (19–21). Marginal leakage studies reported a reduced leakage after use of bonding agent (22–24), whereas others found no significant difference (25, 26).

A good adaptation should prevent marginal discoloration, loss of retention, and marginal decay. Considering the results with the class-III and -V restorations in areas that were acid-etched in this study—0.8% loss of retention and no marginal decay in acid-etched parts of the restorations—it is difficult

to justify the use of a bonding agent in these types of cavity. For the class-IV restorations the situation is more difficult to interpret. A 25% retention failure was observed for this cavity type during the 6 years. It must be kept in mind, first, that most of the failures occurred in patients with bruxism, and, second, that replaced fillings, inserted with an intermediate resin, also failed.

It can be assumed that the patients' functional and especially their parafunctional habits constitute a major reason for loss of retention in class-IV fillings.

The main reason for introducing microfiller resins was their superior surface smoothness. It was shown in an in vitro study that the smoothness remained after toothbrush–dentifrice wear (27). The smoothness of microfiller restorations was evaluated and was found to be retained, compared with the surface roughness of the macrofiller composites, in a scanning electron microscope (SEM) study of 3- to 4-year-old resin fillings (28). The clinical assessment made in the present study confirms these observations. It has been stated that the rough surface characteristics of the conventional resins promote gingivitis, recurrent caries, and staining of the fillings. In two cross-sectional and one experimental gingivitis study, however, no significant differences were found in the degree of gingivitis around the three resin types (29, 30). On the other hand, subclinical gingivitis, as measured by the crevicular fluid flow, was always present around the resins, even in patients with ideal oral hygiene (30). This was explained on the basis of the small bacterial deposits retained on the fillings, which were detected by SEM (28) but not by the clinical examinations (30). No correlation was found in this study between recurrent caries increment and the surface characteristics of the resin types. Other factors like voluminal shrinkage, decreased marginal quality, plaque adhesion, and the patients' caries risk factors certainly play a more important role than the surface roughness of the resin material.

The main reason for replacement of the resin fillings in this study was recurrent caries followed by poor marginal adaptation, loss of retention, and discoloration. Mjör (31) has reported, on the basis of questionnaires, that poor anatomical form was the major reason (41%) for replacing tooth-colored fillings in private practice, followed by recurrent caries (20%) and intrinsic discoloration (13%). More than half of these restorations were replaced within 7 years, and most of these had been in service for 3–7 years. In a later study of the same type, Mjör (32) reported that recurrent caries was by far the most frequent reason for replacing composite resins (43%).

The number of fillings replaced because of discoloration in the present study were underestimated, in my opinion. The frequency of fillings with color changes of score three represents my view on fillings that should have been replaced. There was a difference in opinion between the patients and me about the degree of discoloration that should be regarded as cosmetically unattractive. The patients tended to have a more lenient attitude and sometimes accepted a discoloration of the restorations which I believed ought to be color-adjusted. This has also been reported by other investigators (33).

The frequency of recurrent caries in the present study is in strong contrast to what has been reported in some other clinical studies. In some studies (34, 35) the fillings have served for up to 5 years with a low rate of caries or no recurrent caries throughout the period of the study. It appears that unless a large number of subjects are included in the study, variations in caries susceptibility among individuals must be considered before an evaluation of the frequency of recurrent caries is compared between the materials. When dental students with low caries activity are used as test objects, there is a clear risk that the chance of recurrent caries will be underestimated if the results are extrapolated and interpreted as generally valid. In the present study the frequency of recurrent caries and a caries risk evaluation made for each test person were compared. The different filling materials were evenly distributed in persons with both low and high numbers of risk factors. The different frequencies of recurrent caries contiguous with the various fillings are therefore caused

by true differences between the materials and are not due to variations in caries susceptibility among the test persons. Patients with many negative factors showed clearly a higher caries development, as was also shown for the total caries increment and still more marked for the recurrent caries development contiguous with the composite fillings (compare Figs. 7 and 8).

The predicted caries activity showed a good correlation with the actual caries development. This confirms findings reported in previous studies (10, 36; J. W. V. van Dijken, H. Forsberg, T. Ericson, H. Kollberg. Caries increments and caries risk, evaluation in children with cystic fibrosis. Unpublished observations). The multifactorial nature of the caries disease inevitably disqualifies the use of any single test as sole basis for an evaluation of the caries risk of an individual. Only when several risk values are estimated can we estimate the probability that an individual will acquire dental caries (10; J. W. V. van Dijken, H. Forsberg, T. Ericson, H. Kollberg. Caries increments and caries risk, evaluation in children with cystic fibrosis. Unpublished observations). Six factors were selected, but other factors, such as antibacterial systems, exposure to fluoride, and operator technique, will also affect the actual caries activity. The selection of prophylaxis and choice of restorative material should be based on an understanding of the patients' biological disadvantages.

The fact that 46% of the recurrent carious lesions on buccal surfaces were registered as root caries can be regarded as a contra-indication for composite resins as the material of choice in buccal cavities. In older patients with three or more negative factors one has to reconsider the use of resin fillings, especially in teeth with gingival recessions, which are the teeth at risk for root caries in adult patients (37). The growing body of evidence, which supports the clinical interest in testing the efficiency of fluoride therapy in the prevention of root caries (38), speaks more in favor of the use of fluor-leaking materials like glass-ionomer cement.

During the study large variations in properties were found between fillings of the same resin type. Actually, it was not possible to claim that any type was superior to another. Since the materials are classified in accordance with the content and type of filling material, it is tempting to suggest that the filler component is of minor importance for the durability of a filling. Each composite filling material must be evaluated on its own merits. Any extrapolation from experiences of similar materials must be avoided. We feel that continued observations over a period of 4–6 years is necessary for the final confirmation of longevity of new materials.

It can finally be concluded that the introduction of new resin types has not yet completely satisfied the need for a durable anterior restorative material.

Acknowledgement.—This study was supported by a grant of the J. C. Kempes Memorial Foundation.

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Received for publication 11 June 1986