

Marginal adaptation of composite resin restorations placed with or without intermediate low-viscous resin

An SEM investigation

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The marginal adaptation to acid-etched enamel of a hybrid and a microfilled composite resin, placed with or without intermediate low-viscous resin, was investigated *in vivo*. Each of 37 patients received four class III test fillings, one with each filling technique. The evaluation was done with the use of SEM on replicas from the cavity margins, 1 week and 1 year after insertion of the fillings. The observed defects were marginal cracks or fractures, chip fractures, and enamel fractures. In the comparison of the size and volume of the marginal defects no significant differences were seen after 1 week between fillings of the same material placed with or without an intermediate resin. However, after 1 year the hybrid resin fillings with an intermediate resin showed significantly better adaptation than the ones without. No difference was found between the microfilled resin fillings. The hybrid resin fillings showed significantly better marginal adaptation than the microfilled resin fillings after 1 week. A further increase of the differences was observed after 1 year. □ *Bonding agent; clinical study; operative dentistry; replica*

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The introduction of the enamel acid-etch technique by Buonocore (1) was the first major breakthrough in the use of composites in dentistry. The bond between the composite resin and the etched enamel reduced the need for preparations with mechanical retentions. Factors that influence the marginal adaptation of the resins to the etched enamel include viscosity at the time of insertion, polymerization shrinkage, hygroscopic expansion, finishing technique, mechanical properties, and the coefficient of thermal expansion of the resin (2).

Polymerization shrinkage, occurring during the hardening of the composite resins, can cause microcracks or enamel fractures (3-6), which in turn can contribute to premature failure of the bond. When the polymerization shrinkage is not eliminated by the volumetric expansion because of water uptake or when the differences in the thermal coefficient of expansion between

material and enamel are too great, internal marginal stresses can cause fatigue-type failures (2). Occurrence of chip fractures and marginal fractures parallel to the cavity margin have been observed *in vivo* (7, 8).

A controversial question has been whether the composite material can be applied directly to the etched enamel or whether a low-viscous bonding agent should be used, to enhance resin penetration into the etched enamel. Rider & Kennedy (9) suggested that the same mechanism of adhesion and mode of failure occurred in both cases and concluded that the unfilled matrix resin and the bonding agent penetrate the etched enamel equally well. The unpolymerized resin matrix available on the surface of a freshly mixed composite resin is sufficient to provide adequate wetting of the etched enamel. Jacobsen (10) considered that the composite should be inserted into the cavity immediately after mixing, to achieve an optimal flow

and marginal adaptation. No difference in resin tag morphology was seen in vitro between a highly viscous composite resin and an unfilled bonding agent (3, 11–13). The results of laboratory studies on bonding strength are contradictory; some show that the low-viscous resins have little if any effect (9, 14–16), and others indicate an improvement of retention (17, 18).

In some studies (12, 19–24) the use of a bonding agent was shown to reduce micro-leakage, whereas others have shown that it has no effect (17, 25–27).

It is still an open question whether the use of a low-viscosity resin improves the durability of a composite restoration. In a previous study van Dijken et al. (7) observed chip fractures and marginal fractures parallel to the cavity margins around 3- to 4-year-old resin fillings placed without bonding agent.

The purpose of this study was to investigate in vivo the marginal adaptation to acid-etched enamel of a hybrid and a microfilled composite resin, inserted with or without an intermediate low-viscous bonding agent. The evaluation was done with the use of SEM on replicas of the cavity margins 1 week and 1 year after insertion of the restorations.

Materials and methods

Experimental design

Class III composite fillings were placed in either the six upper front teeth (nos. 13–23) or the six lower front teeth (nos. 33–43) in 37 adults. Each patient received two hybrid and two microfilled composite fillings (Miradapt[®], batch 3J908, Johnson and Johnson Ltd., New Brunswick, N.J., USA; and Silar[®], batches 8601 A and B, 3M Dental Products, St Paul, Minn., USA). One of the hybrid resin fillings was combined with one low-viscous bonding agent (Adaptic Enamel Bond[®] (AEB), Johnson and Johnson Ltd.), and one of the microfilled resin fillings was placed with another low-viscous bonding agent (Scotchbond[®] (SB), 3M Dental Products). The bonding agents used are recommended by the manufacturers of the composite resins.

Experimental procedure

When possible, the cavity margins were beveled, and the unsupported enamel of the other margins, mostly gingival margins, was removed with finishing burs used at low speed. The cavities were isolated with rubber dam and then cleaned with a surface-active cleanser (Tubulicid-blue[®], Dental Therapeutics Ltd., Ektorp, Sweden). A base of calcium hydroxide (Dycal[®], LD Caulk Co., Milford, Del., USA) was applied before the acid etching of the beveled cavity margins for 60 sec with 37% phosphoric acid. After being thoroughly sprayed with water (30 sec) and dried with compressed air, the bonding agent and/or composite resin was inserted. Excess bonding agent was removed by a gentle blast of compressed air immediately after placement. During polymerization the composite resin was held under pressure with a polyethylene (Mylar[®]) matrix strip. After 1 week the fillings were finished with a carbide finishing bur (Jet bur no. 7081, 12-fluted, Beavers Dental Products Ltd., Ontario, Canada) followed by an Arkansas stone (Amalgamated Dental Co., London, UK), polishing strips, and the Soflex polishing discs system (3M Dental Products). As a last step the fillings were polished with a fine polishing paste (Jodka-Fluor, Jod Kaliklora fabriken, Gothenburg, Sweden). All fillings were placed and finished by one operator (J. W. V. van Dijken).

Replica technique

Directly after polishing of the restorations and also after 1 year, replica impressions were made of the resin restorations. The surfaces were cleaned with a 5% sodium hypochlorite solution followed by spraying with water and drying with compressed air. A silicone impression material of low viscosity polymerized by an addition reaction (President, Coltène, Altstätten, Switzerland) was used for the negative replica. The impression was replicated in Epon (Fluka AG, Buchs, Switzerland) to obtain a positive casting.

Scanning electron microscopy of the test surfaces

The positive Epon castings were mounted on metal stubs and covered with gold by a standard evaporation technique. They were then studied in a Cambridge Stereoscan S4 scanning electron microscope (SEM). The evaluation of the marginal adaptation of etched margins not subjected to stress was based on photomicrographs at 20- to 2000-fold magnifications. The final evaluations based on the photomicrographs were made blindly.

Statistical analysis

Sizes of the marginal defects were calculated in percentage of the size of the observed filling margin reproducible with the impression material, at 1 week and 1 year. The four test groups (Miradapt with or without bonding agent and Silar with or without bonding agent) were compared with regard to the size of the defects, using the Mann-Whitney U test (28). The difference in size of the marginal defects in each of the filling techniques between the 1-week and 1-year registrations was tested, using the Wilcoxon matched-pairs signed-rank test (28). The null hypothesis was rejected at the 5% level.

The depth and volume of the marginal defects were estimated subjectively in the SEM pictures and used in combination with the size measurements to rank intra-individually the severity of the marginal defects of each of the test fillings. The filling with the best marginal adaptation obtained rank 1 in the particular patient, the next best rank 2, and so forth. In this manner each patient served as a statistical unit (one degree of freedom). The sums of the ranks in each filling technique were then tested, using Friedman's two-way analysis of variance test (28). If the null hypothesis was rejected, the materials were compared, two at a time, using the sign test (28). The null hypothesis was rejected at the 1% level in each case.

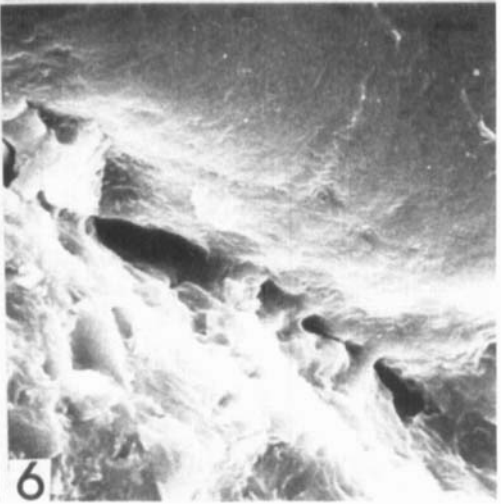
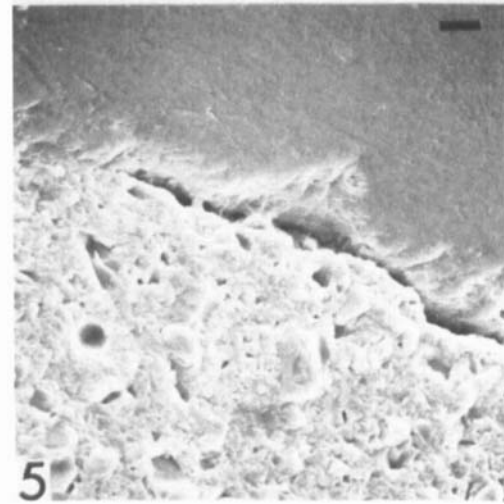
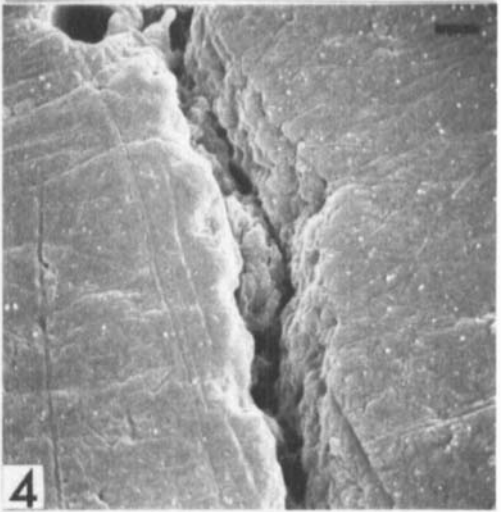
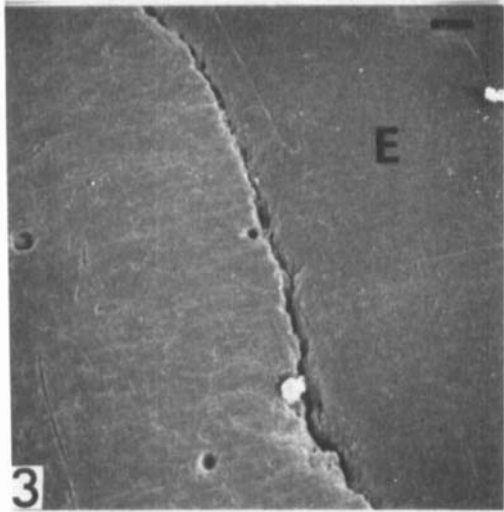
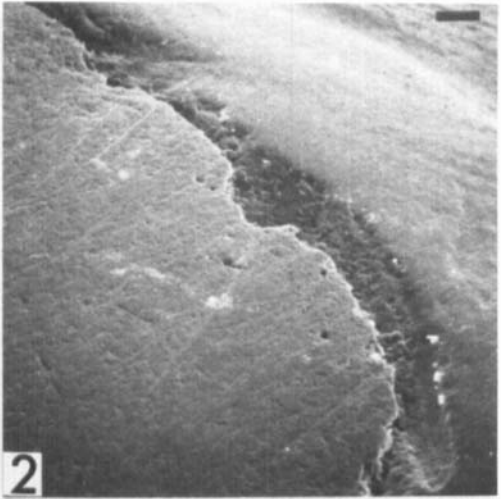
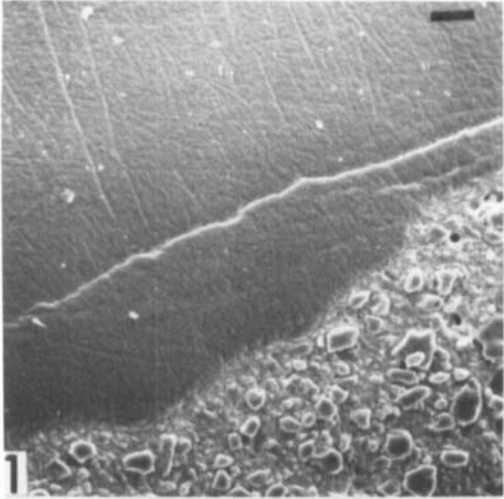
Results

The most commonly observed marginal defects were marginal cracks or fractures,

chip fractures of the filling material, and enamel fractures. Representative defects are shown in Figs. 1-11. The frequencies of fillings with marginal defects, after 1 week and 1 year, for the test groups are shown in Table 1. In each of the test groups more than three of four fillings with defects showed marginal fractures. The microfilled test groups showed generally more marginal defects than the hybrid composite groups.

The mean values of the sizes of the marginal defects expressed as percentages of the acid-etched margin reproducible by the impression material are shown in Table 2. In the comparison of the sizes of the marginal defects between the test groups, no significant difference was seen at 1 week, either between the Miradapt or between the Silar test groups. Miradapt fillings with bonding agent showed significantly smaller defects than the Silar fillings ($p < 0.01$), whereas the Miradapt fillings without bonding agent differed significantly only from the Silar fillings without bonding ($p < 0.05$). At 1 year the Miradapt fillings without bonding agent showed larger defects than the ones placed with bonding agent ($p < 0.01$), whereas no difference was seen between the Silar fillings. The Miradapt fillings with bonding agent showed smaller defects than the Silar fillings ($p < 0.001$). No difference was seen between the Miradapt fillings without bonding and the Silar with bonding, whereas Miradapt without bonding differed significantly from Silar without bonding.

The sum of the ranks of the intraindividual comparisons between the four test groups, when the severity of the marginal defects also was compared, are shown in Table 3. No difference was seen either between the Miradapt test groups or between the Silar test groups after 1 week. The hybrid resin fillings, both with and without bonding agent, showed significantly better marginal adaptation than the microfilled resin fillings ($p < 0.01$ and $p < 0.05$, respectively). After 1 year there was a significant difference between Miradapt with bonding agent and Miradapt without bonding agent ($p < 0.01$), but there was no difference between the Silar test groups. The hybrid fillings both with and without low-viscous resin showed after 1 year



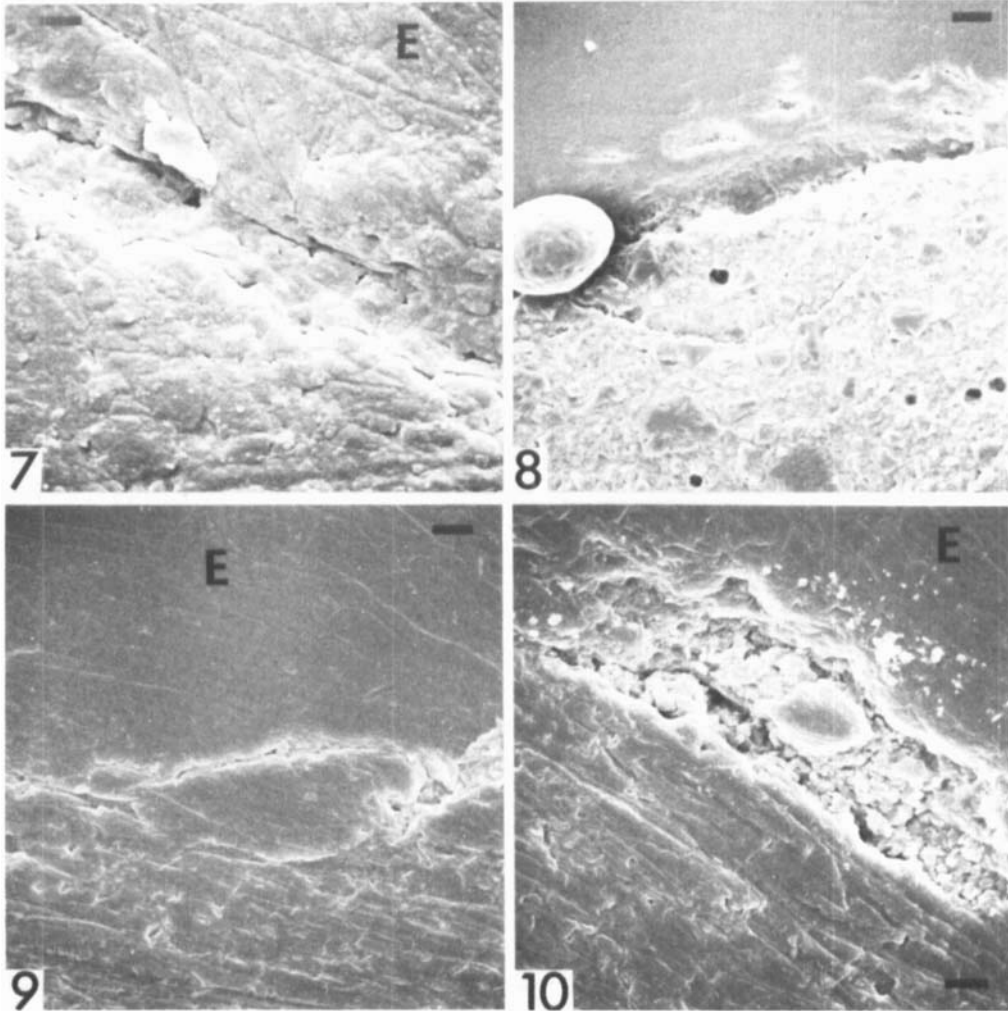


Fig. 7. Crack formation between enamel and bonding agent and between bonding agent and composite resin in Silar filling with SB. Bar = 8.3 μ m.

Figs. 8 and 9. Crack formation in Miradapt filling with AEB (Fig. 8) and in Silar filling with SB (Fig. 9). Bar = 17 μ m.

Fig. 10. Marginal breakdown of Silar filling without SB. Bar = 17 μ m.

Fig. 1. Enamel fracture in Miradapt without AEB filling. Bar = 42 μ m.

Fig. 2. Large chip fracture in Silar with SB filling. Bar = 42 μ m.

Fig. 3. Marginal defect in Silar filling without SB. Bar = 42 μ m.

Fig. 4. Higher magnification of Fig. 3. Pores visible. Bar = 83 μ m.

Fig. 5. Marginal defect in Miradapt filling with AEB. Bar = 17 μ m.

Fig. 6. Higher magnification of marginal defect shown in Fig. 5. Bar = 42 μ m.

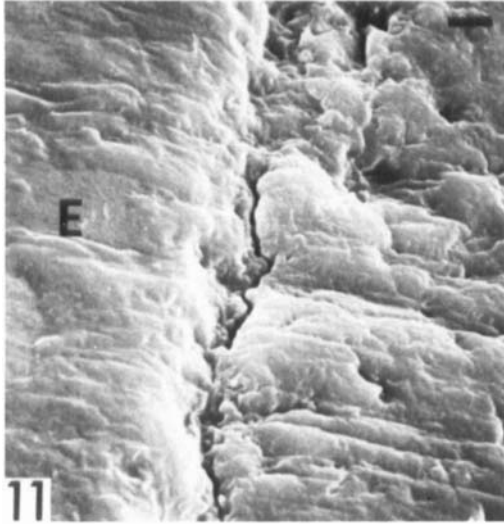


Fig. 11. Small crack visible in Silar filling without SB. Bar = 42 μ m.

significantly better adaptation than the Silar fillings ($p < 0.001$ and $p < 0.01$, respectively). The 1-year registrations showed significantly worse marginal adaptation for all test groups than the 1-week registrations ($p < 0.001$).

Discussion

The greater polymerization shrinkage of the microfilled resins in combination with a higher coefficient of thermal expansion (29) resulted in significantly more and severer marginal defects than the hybrid resin fillings. After 1 year the microfilled resin fillings showed a marked loss of marginal adaptation

Table 2. Size of the marginal defects in percentage of the size of the filling margin: mean (range)

Filling	1 week	1 year
Miradapt + AEB	1.5 (0-7.4)	3.3 (0-15.6)
Miradapt - AEB	3.4 (0-2.8)	8.6 (0-42.0)
Silar + SB	4.7 (0-14.7)	10.8 (0-42.0)
Silar - SB	6.0 (0-19.8)	13.0 (0-38.2)

Table 3. Sum of the ranks of the intraindividual comparisons of the quality of the marginal adaptation for the filling techniques

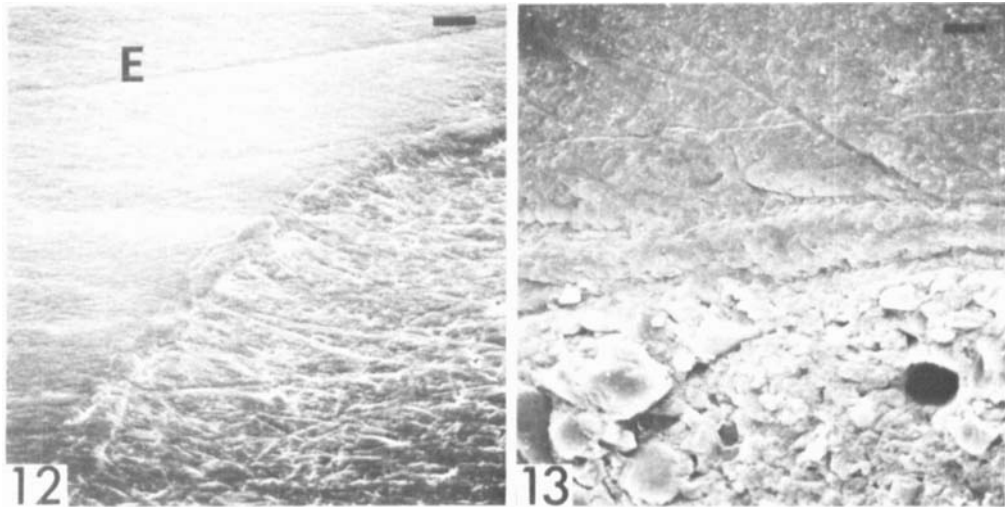
	Miradapt + AEB	Miradapt - AEB	Silar + SB	Silar - SB
1 week	56.0	66.5	88.5	89.0
1 year	51.0	78.5	97.5	103

regardless of whether bonding was used. The hybrid resin fillings placed with bonding agent showed a relatively good marginal adaptation after 1 year, whereas the ones made without bonding showed evident loss of marginal adaptation. These differences were not seen after 1 week.

The results of the present SEM study confirm the previously reported high frequency of marginal defects of chemically cured microfilled resins (7, 8). In contrast, Hansen et al. (30), using a clinical registration system, found a reduced frequency of marginal gaps when a low-viscous resin was used before insertion of light-cured microfilled resins. However, smaller initial stages of defects, the most frequent type of failure

Table 1. Frequency (%) of fillings with marginal defects

Filling technique	Marginal fracture		Chip fracture		Marginal and chip fracture (total)		Enamel fracture	
	1 week	1 year	1 week	1 year	1 week	1 year	1 week	1 year
Miradapt + AEB	29.7	54.1	8.1	27.0	32.4	59.5	5.4	21.6
Miradapt - AEB	32.4	67.6	8.1	37.8	37.8	83.8	8.1	21.6
Silar + SB	51.4	81.8	27.0	46.0	59.5	89.2	8.1	16.2
Silar - SB	46.0	67.6	32.4	51.4	59.5	86.5	13.5	29.7



Figs. 12 and 13. Bonding layer visible in margins with good adaptation of Silar (Fig. 12) and Miradapt (Fig. 13) fillings placed with bonding agent. Bar = 42 μm (Fig. 12) and 17 μm (Fig. 13).

during the 1st year of the resin fillings, can not be registered by the probe.

The low-viscous intermediate resin layer, suggested to be the weakest point in the system, could be observed in several cases, despite the use of a gentle air flow when the bonding agent was applied (Figs. 12 and 13). This means that the high-viscous restorative materials do not always press out the low-viscous resin during application. Separation and fractures were found both between enamel and bonding agent and between bonding agent and composite material.

Fracture of the marginal enamel has been reported by several investigators (4, 6, 31, 32) to result from the force exerted by the polymerization contraction of the resin. Barnes (13) showed similar enamel cracks also in non-etched teeth, in which no tensile stress could have been exerted on the enamel by the contracting filling. He explained these cracks as partly being imperfections of the enamel structure or fractures caused during cavity preparation. A wide bevel and a delay in finishing of the margins decreased the occurrence of enamel fractures (4, 6). Although enamel fractures were found in around 5.4–29.7% of the fillings in the present study, marginal defects like cracks and fractures were the major failures. This indi-

cates that the enamel–resin interface is a weaker link than the enamel itself. Furthermore, the higher incidence of enamel fractures in the 1-year-old fillings indicates the importance of the thermo-mechanical stress in the mouth as a cause of enamel defects.

Since the retentive strength of composite resin fillings placed without intermediate resin has been shown to be satisfactory (33–36), the clinical importance of the failures in marginal adaptation is dependent on whether microleakage of microorganisms and/or acids and toxic products can occur.

The prevention of microleakage around the filling requires a sufficiently thick enamel layer at the cervical margin; otherwise the acid-etch technique cannot be used. Large gaps will occur if only a part of the margins is acid-etched (37, 38). Bacterial penetration can then easily occur along the cervical margins. A longitudinal clinical study (33) showed that the cervical margins were the margins most prone to caries, while no caries occurred at the etched margins. Kidd & Roberts (39) demonstrated in an artificial-caries study that the etched margins afforded a good cavity seal irrespective of whether an unfilled resin was used as an intermediary layer. The failures occurring in the acid-

etched area did not seem to lead to caries in anterior composite resin fillings.

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