Microleakage of indirect composite inlays

An in vitro comparison with the direct technique

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Microleakage occurring around directly and indirectly made class-II composite restorations was evaluated on extracted human premolars. Before the evaluation was made, the teeth were thermocycled and stained with an organic dye. Direct class-II composite restorations demonstrated extensive microleakage at their dentin cavosurface margins. Indirect class-II composite inlays luted with a dual-curing composite cement displayed much less microleakage than restorations made using the direct technique. The use of glass-ionomer cement rather than composite cement as the luting material resulted in more microleakage. Rather than being a true microleakage, the leakage of glass-ionomer cement might be the result of a diffusion of the water-soluble organic dye in the water-based cement. The results suggest that the indirect composite technique is superior to the direct technique when it comes to reducing microleakage. □ *Dental composites; inlays; in vitro study; microleakage*

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Composite materials are being used increasingly as material for restorations. The main problem associated with class-II composites is poor marginal adaptation. Polymerization shrinkage and competing composite–tooth adhesive bond are two factors that determine whether marginal gaps will develop. The presence of interfacial gaps promotes microleakage, marginal discolorations, tooth sensitivity, bacterial invasion, and, eventually, secondary caries (1). The problems associated with inadequate sealing are most pronounced in large class-II cavities, in which the enamel border is thin or even missing (2, 3).

Several methods, such as incremental build-up techniques, sophisticated curing techniques, and the use of intermediate layers with bonding ability (4–7), have been suggested as means of reducing microleakage. So far, no method has completely eliminated marginal leakage (4).

Reduced microleakage might be achieved by extra-oral fabrication of the restoration and subsequent luting with dual-curing composite cement (8). Such a reduction would be due primarily to a smaller volume of intraorally shrinkable material (4, 9).

The objective of the present in vitro study was to compare the microleakage around class-II cavities restored with composite material using either the direct or the indirect technique. In the case of the indirect technique, the effect of two different polymerization methods and luting materials on the microleakage was evaluated.

Materials and methods

Cavity preparation

Fifty single approximal class-II cavities were prepared in extracted human premolars. Only caries-free teeth with no visible cracks were used. Non-conservative class-II cavity preparations were cut with a conical diamond (Ra value, 120 μm), using high speed and ambient water. The proximal boxes extended well beyond the cemento-enamel junction (CEJ). The size and non-beveled outline of the cavities were standardized. The cavity preparations were finished using a slowly rotating medium-coarse diamond. Throughout the test procedure the teeth were stored in water at 20 ± 1°C. Ten teeth were randomly selected from each of the five experimental groups (Table 1). Before the restorative procedure, all the cavities were cleaned with a cotton pellet soaked in Tubulicid (Dental Therapeutics AB, Nacka, Sweden). No liner was used in any of the cavities.

Restorative procedure

Group I. The enamel margins were etched for 30 sec with 35% phosphoric acid gel (Acid Etchant, ICI Pharmaceuticals Division, Macclesfield, Cheshire, England), followed by thorough washing and drying. Bonding Agent (ICI Pharmaceuticals Division) was applied to the etched surfaces and thinned with a stream of compressed air. The cavities were filled incrementally with a posterior composite material (Occlusin, ICI Pharmaceuticals Division). Each increment was light-cured for 30 sec (Luxor Model 4000, ICI Pharmaceuticals Division). The samples were stored in water at 32 °C for 24 h before being thermocycled.

Groups II and III. The teeth were restored with the same posterior composite as in group I but by means of the indirect technique. Individual impressions were taken of each of the prepared teeth using a polyvinylsiloxane impression material (Provil L, Bayer, Leverkusen, Germany), and two individual stone casts were poured, using a type-IV dental stone (Silky Rock, Whip Mix Corp., Louisville, USA). The inlays were made on dies without any separating medium. The same incremental and curing technique as that used in test group I was used. The inlays were finished with graded Soflex discs (3 M Dental Products, St Paul, Minn., USA), whereafter they were removed from the dies and checked for fit on the master models. Finally, the inlays were stored in water at 32°C for 24 h before being luted.

Groups IV and V. The teeth were restored with SR-Isosit Resin (Ivoclar, Lichtenstein). The same procedure as that described for test groups II and III was used to prepare the stone casts. The inlays were then made in accordance with the manufacturer's instructions. SR-Separating Fluid (Septor, Ivoclar) and a layer of activated SR-isosit-N Fluid were place on the cast, whereupon the SR-Isosit Resin Material was placed in the stone cavity. After being contoured, the surface was covered with a thin layer of SR-Isosit-N-activated fluid. The die with the unpolymerized resin inlay was submerged in water in an Ivomat (Ivoclar), and the resin was polymerized at 120°C and 6 bar pressure for 10 min. The polymerized inlay was easily removed from the softened stone model, and the fit was checked on the master model. The internal surfaces of the inlay were sandblasted with aluminum oxide with a particle size of 100 μm and at a reduced pressure of 2 bars. The inlays were stored in water at 32 °C for 24 h before they were luted.

Luting procedure

Dual-curing composite cement. The enamel margins of the teeth prepared for inlays were etched for 30 sec with a 35% phosphoric acid gel followed by thorough washing and drying. The mixing and handling of the dual-curing composite cement (Micropont, Kulzer & Co GmbH, Wehrheim, Germany) was done in accordance with the manufacturer's instructions. Immediately after seating, any gross excess of composite cement was removed with a brush soaked in enamel bonding agent. Light-curing was started occlusally, and every part of the inlay was light-cured for 40 sec.

Glass-ionomer cement (GIC). The cavities were pretreated with a short application of 10% polyacrylic acid. The glass-ionomer cement (GIC) (AquaCem, DeTrey GmbH,

Table 1. Experimental groups

Group	No. of teeth	Restoration: Method	Restoration: Material	Luting material
I	10	Direct	Occlusin	None
II	10	Indirect	Occlusin	Dual*
III	10	Indirect	Occlusin	GIC†
IV	10	Indirect	Sr-Isosit	Dual
V	10	Indirect	Sr-Isosit	GIC

* Dual-curing composite resin cement.
† Glass-ionomer cement.

Wiesbaden, Germany) was mixed and handled in accordance with the manufacturer's instructions. The tooth surfaces were kept slightly moist with a water-moistered cotton pellet, to optimize the conditions for bonding to tooth structures. Once in place, firm finger pressure was maintained on the inlay during setting. Immediately after the seating, excess cement was removed with a cotton pellet.

Thermocycling procedure

All the specimens were stored in water at 32°C for 24 h before being thermocycled. The teeth in the five test groups were thermocycled 1500 times between 5 and 55°C with a dwell time of 15 sec. After the thermocycling, the teeth were stored in water at 32°C for another 120 h before the microleakage staining procedure.

Microleakage staining and analyzing procedure

Each tooth was removed from the water and dried carefully in a stream of compressed air. The apex was sealed with sticky wax, and the entire tooth was coated twice with nail varnish, apart from a 1-mm-wide zone adjacent to the margins of the composite restoration/inlay. The teeth were immediately transferred to a 2% aqueous solution of methylene blue, in which they were stored at 32°C for 24 h. The methylene blue storage was followed by a short rinse in water. The roots were cut off 2–3 mm apically from the cervical border of the restoration/inlay and embedded in a casting resin (Castolite Resin, Buehler Ltd, Lake Bluff, Ill., USA). Using a slowly rotating diamond saw (Isomet, Buehler Ltd) with kerosene (J T Baker Chemicals BV, Deventer, Holland) as the lubricant, the teeth were sectioned mesiodistally through their long axis. The sectioning resulted in two approximately equal parts, which were both analyzed for microleakage. The sections were coded and were analyzed under a stereomicroscope (Stereo Microscope No 7, Bauscher, Rochester, N.Y., USA) at ×50. Each section was photographed and the degree of microleakage was evaluated in accordance with Table 2.

Differences in leakage scores between the various groups were compared using the Wilcoxon rank sum test. The level of significance was set at $p < 0.05$.

Results

The results of the microleakage evaluation in the five test groups are shown in Table 3. A total of five teeth were excluded in groups I, IV, and V owing to the presence of cracks that had not been detected before the microleakage staining test.

Table 2. Microleakage evaluation score

Score	Description of microleakage level
Restoration/Inlay outer margin on enamel	
0	No microleakage
1	Microleakage along the enamel not reaching the dentinal junction
2	Microleakage extending beyond the enamel–dentin junction
3	Microleakage along the floor of the cavity
4	Microleakage reaching the pulp
Restoration/Inlay outer margin on dentin	
0	No microleakage
1	Microleakage along the cavosurface only
2	Microleakage along the gingival floor only
3	Microleakage along the gingival floor and extending up the axial wall
4	Microleakage reaching the pulp

Table 3. In vitro microleakage between restoration and enamel or dentin

Group	No. of teeth	Luting cement	Leakage score†									
			Enamel/restorative					Dentin/restorative				
			0	1	2	3	4	0	1	2	3	4
Direct Occlusin (I)	9*	None	9									9
Indirect Occlusin (II)	10	Dual	10					7	1	2		
Indirect Occlusin (III)	10	GIC		8	2					3	2	5
Indirect Isosit (IV)	8*	Dual	8					6	1	1		
Indirect Isosit (V)	8*	GIC	2	6					1	5	1	1
Total	45		29	14	2			13	3	11	3	15

* Teeth excluded owing to presence of cracks.
† Groups connected by a line are statistically equivalent.

Cavosurface in enamel

No difference in leakage pattern could be seen between the directly made composite restorations and the indirectly made composite restorations luted with the dual-curing composite cement, as long as the tooth–restoration interfaces were placed in the enamel (Table 3). Composite inlays luted with GIC showed some degree of microleakage. With the exception of 2 of the 18 test teeth, the leakage was restricted to the margin or extended slightly along the enamel without reaching the enamel–dentin junction (84%; score, 0–1).

Cavosurface in dentin

All the directly made composite restorations with cavosurface margins placed in root dentin or cementum obtained the highest microleakage score.

Most of the indirect composite inlays luted with a dual-curing composite cement (83%) showed little or no microleakage (Table 3). Composite inlays luted with GIC demonstrated a higher microleakage score than the inlays luted with a dual-curing composite cement. Ninety-four per cent had a leakage score of 2–4. When GIC was used as the luting material, the cavosurface margins located at the dentin obtained higher leakage scores than those located at the enamel. Furthermore, Occlusin inlays luted with GIC demonstrated higher leakage scores (70%; score, 3–4) than Isosit inlays (25%; score, 3–4). In a few specimens a dye leakage line was observed between the inlay and the GIC, but bulk leakage appeared to be more frequent.

The Wilcoxon rank sum test showed a significant difference between group I (Direct Occlusin) and all other groups (II–V) in terms of microleakage at the dentinal margins. No significant difference could be found between the two inlay materials when a dual-curing composite cement was used. However, the use of GIC as a luting material showed a significant difference ($p < 0.05$). The comparison between each inlay material and the two luting materials resulted in a significant difference in microleakage between the luting materials (Table 3).

Discussion

The marginal adaptation of restorative materials is a matter of key concern in dentistry. In the case of the tooth-restoration interfaces in enamel, in the present study no leakage was registered and no difference in microleakage could be seen between composite restorations and composite inlays, provided that dual-curing composite cement was used as the luting material. This finding supports the results of Hasegawa et al. (10). However, Lundin & Norén (11) found various extents of in vitro microleakage along the cervical enamel margins in modified class-II composite restorations. These authors found a significantly higher microleakage when a calcium-hydroxy liner was used and the restorations were loaded mechanically, which might be due to the poor mechanical properties of the liner and the effects of mechanical stresses at the enamel–restoration interface. In the present study and in the study of Hasegawa et al. (10) the restorations were not loaded mechanically, nor were any liners used.

The placement of the cervical margins on the root dentin resulted in extensive microleakage when the direct restorative technique was used, which agrees well with the findings in other studies (12–14). The volumetric shrinkage process during the setting of composite resin materials is regarded as the main reason for the development of interfacial gaps (15). Gap sizes varying from 7 to 22 μm have been registered in vitro for various composite materials and bonding procedures (16). The suggested positive effect of the incremental technique on microleakage (5) could not be verified in the present study.

Indirect composite inlays luted with a dual-curing composite cement had a much lower frequency of in vitro marginal leakage along the cervical dentinal margin than did direct composite restorations. This observation is in agreement with other studies (10, 17) and can be explained by assuming that the interfacial bonds are not challenged by the bulk shrinkage of the composite material when the indirect technique is used. However, the dentinal bond must still withstand the polymerization stresses of the dual-curing composite cement. According to Feilzer (15), these forces must not be underestimated, as the compensatory mechanism for the volumetric shrinkage is limited. The leakage seen in the inlay groups could be attributed to shrinkage stresses from the composite cement, air bubbles incorporated at the interface, or incomplete bonding. The interfacial stress level might be reduced by the yield of buccal and lingual cavity walls (18), by the presence of porosities in the luting material producing free surfaces within the cementing medium (15), and by expansion through water absorption (15), thereby reducing the strain on the tooth–inlay adhesive bond.

Marginal leakage occurring in vivo is very difficult to detect and can only be found through indirect observations (19). Owing to the lack of appropriate clinical methods, most microleakage studies of restorative materials and luting agents are conducted in vitro. Microleakage studies often produce conflicting results; this is due in part to the presence of too many influencing variables. In the present study the number of variables was intentionally reduced. Several techniques for detecting microleakage have been suggested in earlier studies (20). Dye penetration is regarded as a severe microleakage test, as the size of the methylene blue molecule is extremely small in comparison with that of bacteria (9). However, very small gaps may permit the passage of bacterial toxins and nutrients, offering a substrate for the bacteria already present in the interface. In the present study all the restored teeth were stored in water at 32°C for 1 week before they were microleakage-stained, thus permitting the major part of the hygroscopic expansion of the microfilled composite luting material to take place before contact with the organic dye solution (21).

A more pronounced marginal leakage at the dentinal cavosurface was registered in both types of composite inlay when GIC was used as the luting material. The adhesion of GIC to enamel and dentin occurs through polar interaction between carboxyl groups and calcium ions. In addition, bonding to amino groups of the collagen has also been reported (7). No chemical bonding to the composite occurs. Whether the use of GIC inhibits or merely reduces the marginal leakage is a matter of controversy (14, 22, 23). Several possible pathways of leakage may exist—between the inlay and the GIC, between the GIC and the tooth substance, or within the bulk of the GIC. Bulk absorption of the water-soluble tracer could be attributed to the hydrophilic nature of the GIC (23, 24). However, the more pronounced microleakage at dentinal margins than at enamel ones might be explained by incomplete bond formation between GIC and dentin and by the increased exposure of the luting cement due to axial displacement of the inlay during cementation. The different leakage patterns for Occlusin and Isosit inlays, as seen in the present study, are more difficult to explain. It is possible that the different treatment of the internal surfaces of Occlusin and Isosit inlays could result in a different interlocking of the luting cement.

Microleakage appears to be an inevitable phenomenon of restorative and luting materials. Restorations with dentin cavosurface interfaces are prone to leak. The present study shows that the composite inlay technique is successful in reducing the incidence of in vitro marginal leakage along the restoration–dentin interface. It also demonstrates that composite inlays luted with GIC obtained higher leakage scores than those cemented with a dual-curing composite cement. The microleakage associated with composite resin restorations and inlay therapy might be a matter of greater concern for the clinician than the leakage associated with GIC. What is judged as microleakage when using GIC might, at least in part, be a simple diffusion process with less serious clinical implications than the existence of 'true' interfacial gaps. Furthermore, it has been suggested that GIC as a restorative or luting material has bacteriostatic/bactericidic properties (25, 26).

The clinical impact of these findings is difficult to assess. However, the use of the indirect technique appears to be one way of reducing microleakage in composite restorations, a finding that might also be relevant in vivo.

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