Interfacial adaptation of a Class II polyacid-modified resin composite/resin composite laminate restoration *in vivo*

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The aim of this *in vivo* study was to evaluate the interfacial adaptation of Class II resin composite open sandwich restorations with a polyacid-modified resin composite as a stress-absorbing layer (PMRC/RC). Twenty Class II box-shaped, enamel-bordered cavities were prepared in 10 premolars scheduled to be extracted for orthodontic reasons. An open PMRC/RC sandwich restoration was placed in 1 of the cavities of each tooth. The first layer, PMRC, in the proximal box extended to the periphery in the cervical part of the cavity. The following RC layers were placed with a horizontally incremental technique. The PMRC was excluded from the control cavity,. The teeth were extracted after 1 month and the interfacial adaptation of the restorations was studied with quantitative scanning electron microscope analysis using a replicate technique. Gap-free interfacial adaptation was observed for the PMRC/RC and RC restorations in cervical enamel in 97% and 73%, respectively ($P = 0.006$). The gap-free scores for dentin were 87% and 64%, respectively ($P = 0.022$). Excellent interfacial adaptation was observed in both groups for the occlusal enamel 99% and 100%, respectively. The adaptation to occlusal enamel for the direct resin composite restorations was significantly better than to dentin or cervical enamel. A higher frequency of enamel fractures was observed parallel to the cervical margins compared to the occlusal. No dentin fractures were observed in the experimental groups. The PMRC/RC sandwich technique showed a statistically significant improved interfacial adaptation to dentin and cervical enamel in Class II enamel-bordered cavities. The clinical significance of the differences has to be evaluated. □ *Bonding; clinical; composite; laminate; resin*

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During the last decade, interest in alternative filling materials has increased owing to patient demand for aesthetic restorations and also because of their anxiety about mercury in dental amalgam. Posterior resin composite restorations (RC) have previously shown short durability due to non-acceptable sealing and a high wear rate. Recently developed materials are superior when it comes to wear, but still show too high polymerization shrinkage. Volumetric changes, flow capacity and bond strength to enamel and dentin influence the adhesion of filling materials to tooth tissues. The bond of resin-based materials to tooth structure is obtained by the formation of a hybrid layer in demineralized enamel and dentin. Stresses occurring during polymerization of the restoration may weaken or disturb the interfacial adaptation (1). The developed stresses are proportional to the volume of the resin material cured. The greatest stress generates directly during curing and before maximal strength of bonding to the cavity walls is established. Masticatory loads further stress the bonding surface (2). Marginal integrity is crucially important for the durability of a restoration. Adhesive failures can cause hypersensitivity, recurrent caries and pulpal injury (3). Several techniques have been introduced to reduce the stresses. Restricting the volume of RC in sandwich or laminate restorations can reduce the shrinkage. Resin composite inlays have shown superior marginal seal compared to direct RC restorations (4, 5). In small cavities, resin composite fillings show good durability (6–8). However, in larger Class II cavities the shrinkage may result in lack of adaptation, especially to the cervical cavity walls of the proximal box and thereby increase susceptibility to caries (3, 9).

In Class I resin composite fillings performed *in vivo* with modern dentin bonding systems a constant detachment of the adhesive resin from the underlying hybrid layer was observed (10). A good seal was observed *in vitro* when a sufficiently thick and relatively elastic unfilled or semi-filled adhesive resin layer was placed in Class V fillings (11). It has been suggested that this layer may absorb polymerization shrinkage stress of the resin composite by elastic elongation (12).

Polyacid-modified resin composites (PMRC) include resins with a modulus of elasticity value between those of RC and glass ionomer cement (GIC) (13). A stress breaking function can therefore be expected to occur by the additional use of an intermediate layer of PMRC. Previous laboratory investigations of PMRC/RC laminate restorations have shown high percentages of “satisfactory adaptation” in enamel and dentin (14–16).

The aim of this *in vivo* study was to evaluate with a quantitative scanning electron microscopic marginal analysis technique the interfacial adaptation of Class II PMRC/RC open sandwich restorations placed *in vivo* by a horizontal multilayering technique.

Table 1. The interfacial breakdown scores

1.	Good adaptation, no interfacial opening, no deficiencies.
2.	Slight marginal irregularities.
3.	Severe marginal irregularities, no crack visible.
4.	Hairline crack, wider gap with bottom visible.
5.	Severe gap, bottom hardly or not visible.

Material and methods

Ten premolars scheduled for extraction for orthodontic reasons were available after parental consent was given for the study, which was approved by the Ethics Committee of the University of Umeå. All teeth were in occlusion. To anaesthetize the experimental teeth, 3% Citanest-Octapressin (Astra, Södertälje, Sweden) was placed. In each tooth a mesial and a distal box-shaped Class II cavity were prepared with a cylindrical diamond bur in a high-speed handpiece with copious water-cooling.

The bucco-lingual distance of the preparations was about 4 mm wide and the axial depth 1.5–2 mm. No bevels were prepared and all cervical margins were located in enamel. Metal matrix bands were used in combination with careful application of wooden wedges. The operative field was isolated with cotton rolls and a suction device. All materials were applied according to the manufacturer's instructions.

The cavities were acid-etched with 35% phosphoric acid (Ultradent etch, Ultradent, USA) for 15 sec, starting with the enamel margins for the first 10 sec. They were then thoroughly rinsed with water for 15 sec and carefully dried for 2–3 sec, allowing a wet technique to be used (17). A self-etching primer (Prime & Bond 2.1, DeTrey/Dentsply, Konstanz, Germany) was placed within the cavity for 30 sec. The acetone was removed from the primer by air-drying briefly, followed by a light-cure for 10 sec. A second layer of Prime & Bond 2.1 was placed, immediately air-dried and light-cured for 10 sec.

One of the cavities in each of the experimental teeth was filled using a PMRC/RC open sandwich technique. A PMRC (Dyract, Dentsply/DeTrey) was placed as the first layer in the cervical part of the cavity, while the following layers were placed with a resin composite (Prisma TPH, Dentsply/DeTrey). Each layer, all less than 2 mm thick, was light-cured for 60 sec with a regularly controlled light-curing unit. After removal of wedges and metal matrices the fillings were light-cured from buccal and lingual directions for 60 sec each.

The other cavity (control) was filled with RC only (Prisma TPH, Dentsply/DeTrey) in 2 mm layers, which were light-cured for 60 sec each. After removal of the wooden wedges and the metal matrices the fillings were light-cured from a buccal and lingual direction for 60 sec each.

Scanning electron microscope evaluation

After a 1 month service period in the mouth the experimental teeth were extracted. Care was taken not to damage the restorations during the extraction (18). Immediately after the extraction the outer surfaces of the teeth were carefully cleaned. To observe interfacial adaptation, the restorations were sectioned in a mesio-distal direction through the middle of the restorations, with a low speed diamond disk in a handpiece with copious water spray (19). The sections were then planed with medium and fine polishing discs (Sof-lex discs, 3M, St Paul, USA) under continuous water spray in order to minimize smear layer formation. To remove the smear layer the sections were slightly etched with 35% phosphoric acid for 3–5 sec, rinsed with water for 20 sec and briefly dried. Replica impressions were then made of the buccal and lingual sections with a vinylsilicone impression material (President light body, Colténe, Altstätten, Switzerland) (5). The negative impressions were replicated (Epon, TEM bedding-in-resin, Fluka AG, Switzerland) to obtain positive casts. The casts were prepared for SEM by mounting on metal stubs and coating with gold by a standard evaporation technique (18). All interfaces were evaluated with a scanning electron microscope (SEM; Cambridge Stereoscan Microscope) at ×200 and ×1000 and supplemented when necessary with other magnifications. The quality of the interfacial attachments and degree of interfacial breakdown were compared to standard microphotographs of marginal degradations (19). For each restoration the final evaluations were made double blind on the microphotographs. The marginal breakdown scores are given in Table 1 (20). The quality of the interfaces, the degree of marginal opening and breakdown were described as percentages of the total length of the interfaces examined on the microphotographs.

Statistical analysis

The percentages of the interfacial qualities of the tooth tissues between the two restorative techniques were statistically analysed by means of the Mann-Whitney U test performed with the SPSS (Statistical Package for Social Sciences) exact test (20). The test was carried out at the 5% level of significance.

Results

The evaluation scores of the dentin/restoration interfacial quality and the occlusal and cervical enamel/restoration quality are given in Table 2. Excellent interfacial adaptation was observed in both groups for the occlusal enamel (Figs 1, 2). Gap-free adaptation in the cervical enamel was observed in 97% for the open sandwich and in 73% for the direct resin composite restorations ($P = 0.006$). Gap-free

Table 2. Interfacial adaptation scores for the Class II open sandwich polyacid-modified resin composite/resin composite and direct resin composite restorations determined as percentages of the margins examined (%)

		Scores					
Group	No.	1	2	3	4	5	Enamel or dentin fractures
Cervical enamel							
Open sandwich	9	96.9	—	—	0.7	2.4	7.0
Direct composite	10	69.6	3.1	—	1.7	25.6	17.6
Occlusal enamel							
Open sandwich	10	98.8	—	—	0.3	1.0	2.8
Direct composite	10	100	—	—	—	—	2.1
Dentin							
Open sandwich	10	82.9	2.8	1.0	7.5	5.9	—
Direct composite	10	53.6	6.5	3.6	8.7	27.6	—

scores for the dentin were 87% and 64%, respectively ($P = 0.022$). The adaptation to occlusal enamel was significantly better than to dentin in both groups ($P = 0.002$) and to cervical enamel in the direct composite group ($P = 0.001$). Significant differences were found in the open sandwich group between the cervical enamel and dentin scores ($P = 0.029$). Openings and areas with good adaptation were found adjacent to each other (Figs 3, 4). In almost all cases the dentin interfacial failures were found between the hybrid layer and the resin composite (Fig. 4). Tag formation in the dentin tubules was frequently observed (Figs 5, 6). Enamel fractures parallel to the margins were observed with a mean value of 8.7%. The cervical margins showed a higher fracture rate than the occlusal, 15% and 2%, for the direct resin composite and open sandwich restoration, respectively. No dentin fractures were observed in the experimental groups.

Discussion

The most common analysis of interfacial adaptation has been the dye microleakage test, a relatively easy and cheap test which commonly uses extracted teeth (21). This technique is difficult to standardize and the wide range of sealing results reported within the different material groups analysed make this test method difficult to interpret (22). Quantitative marginal analysis with SEM observes

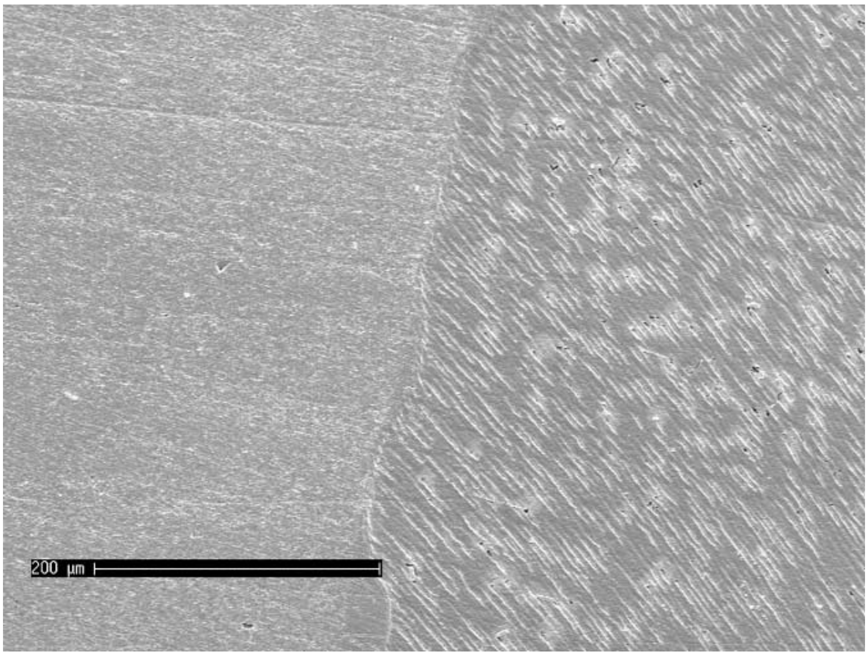

Fig. 1. Excellent interfacial adaptation in the dentin of a class II PMRC/resin composite filling. Original magnification ×200.

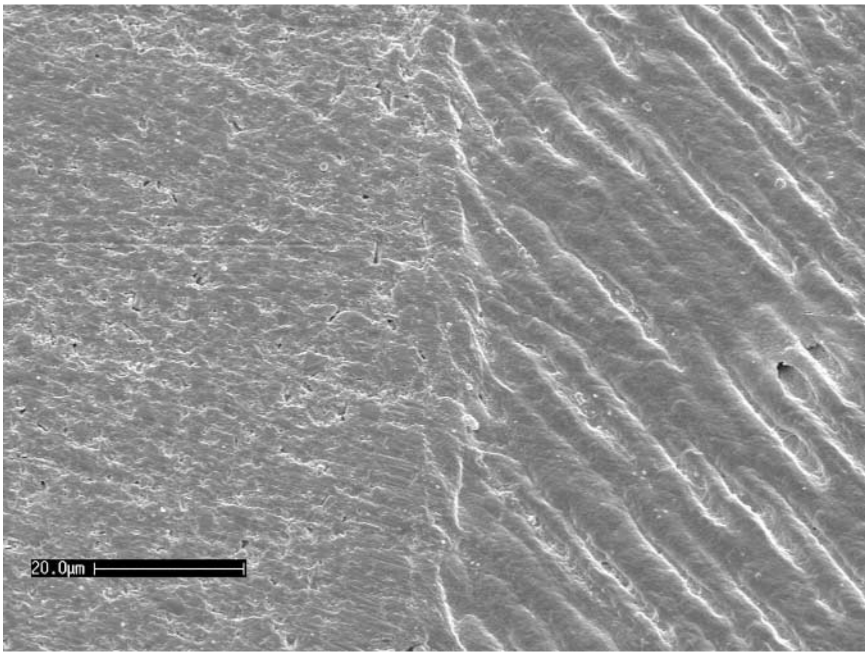

Fig. 2. Higher magnification of the interfacial adaptation shown in Fig. 1. Original magnification ×1000.

bonding surfaces at high magnifications and enables the detection of marginal failure(s) formation at an early stage. A more elegant and clinically relevant way is the *in vivo* evaluation of changes in marginal adaptation over time by using the SEM replica technique (23). Unfortunately, there is no good correlation between the scores for marginal and interfacial adaptation; the marginal adaptation analysis alone will give only limited information (24).

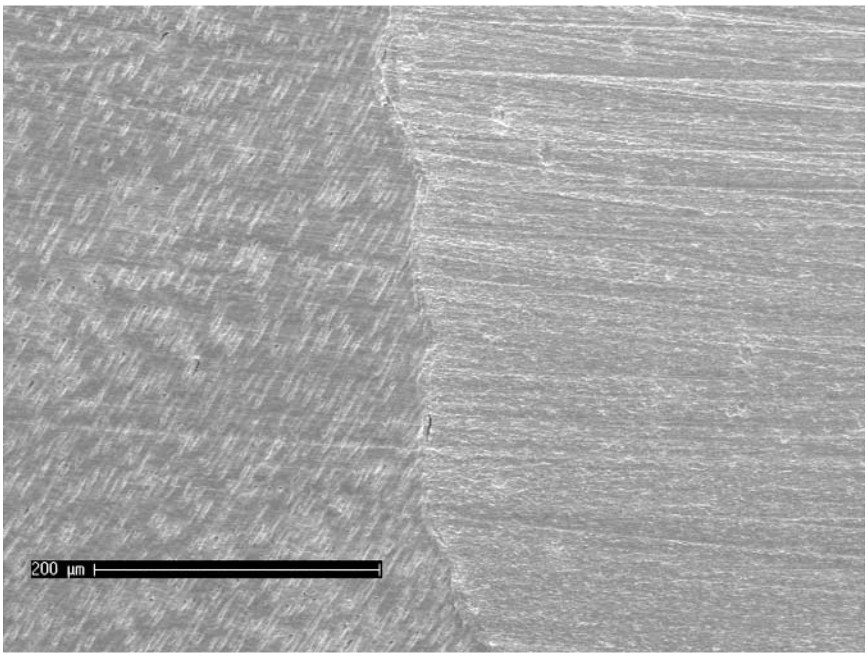

Fig. 3. Gap formation and areas with good adaptation adjacent to each other. Original magnifications ×200.

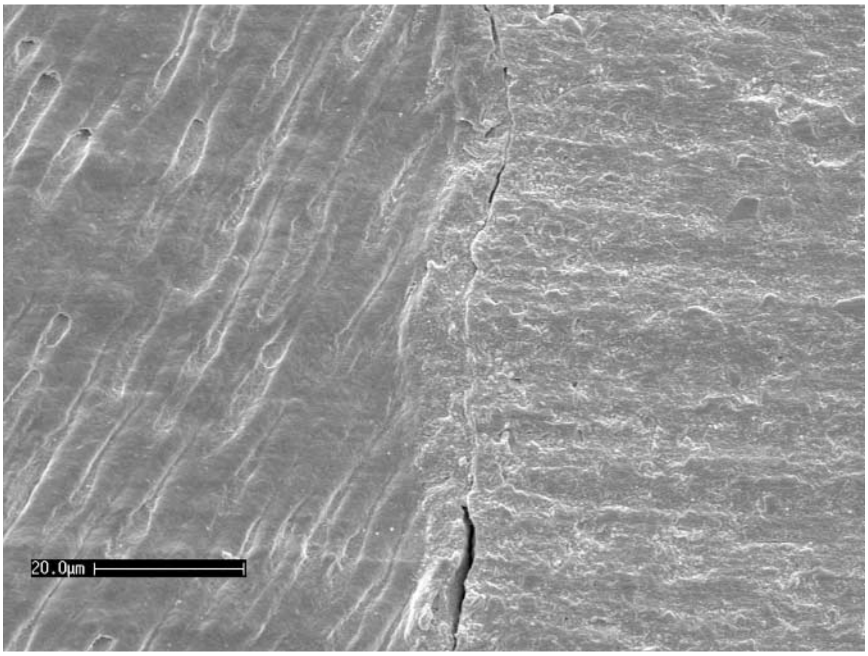

Fig. 4. Gap formation and areas with good adaptation adjacent to each other. Original magnification ×1000. Higher magnification of Fig. 3.

Different incremental placement techniques or combinations of restorative materials have been proposed to overcome or reduce the effects of the polymerization shrinkage of resin composite materials (4, 25–28). The use of a glass ionomer underfilling in the conventional sandwich restoration reduced the bulk resin composite used and in this way improved the marginal adaptation (1, 6, 14, 29, 30). However, clinical studies showed too

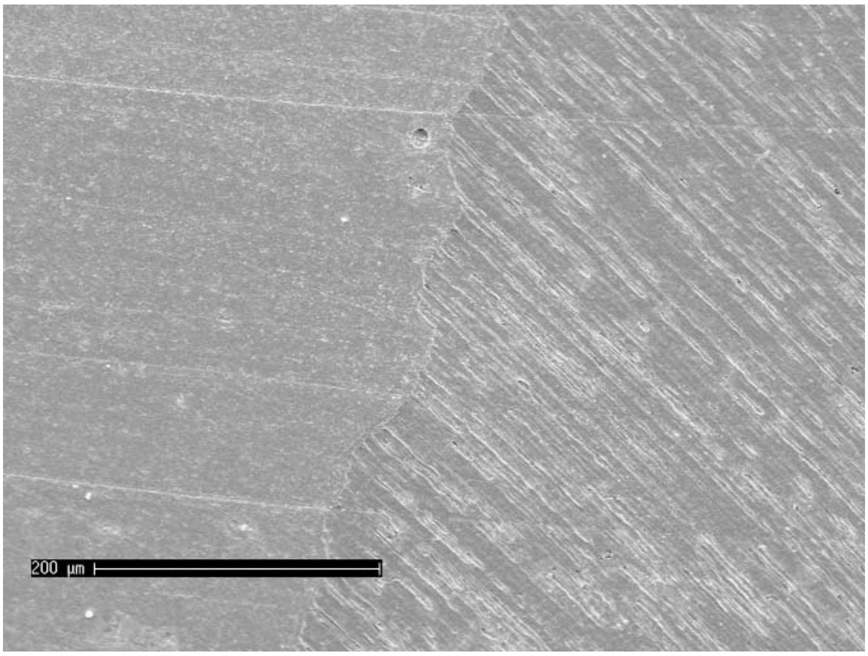

Fig. 5. Excellent interfacial adaptation in a direct resin composite restoration. Original magnification ×200.

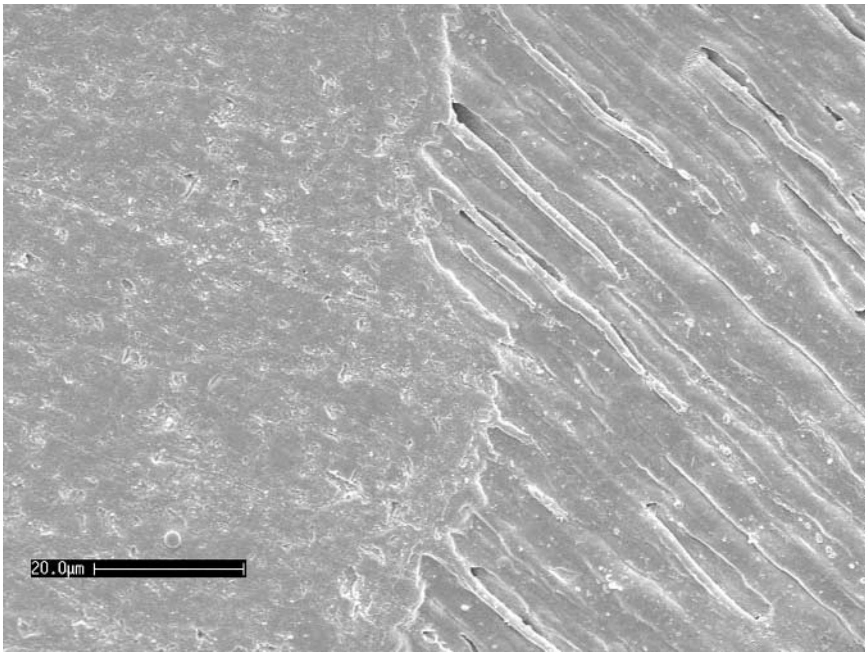

Fig. 6. Excellent interfacial adaptation in a direct resin composite restoration. Long tags can be observed in the dentinal tubulus. Original magnification ×1000. Higher magnification of Fig. 5.

high a failure rate of the restoration due to a continuous loss of the GIC (6, 29, 31). It has been suggested that replacement of the GIC in the open sandwich restoration by resin-modified glass ionomer cement (RMGIC), PMRC, or the use of a chemically cured resin composite, can improve the marginal adaptation and durability of the restoration (14, 19, 28). Friedl et al. (14) obtained *in vitro* no differences in dentin marginal adaptation and a better, but not significant, enamel marginal adaptation for the direct resin composite restoration compared with the same laminate as investigated in the present study. A total etch technique was used before application of the self-etching primer (PSA, Dentsply/DeTrey) in both restorations.

The evaluation of interfacial quality of the laminate restorations in the present *in vivo* study showed a higher frequency of gap-free dentin and cervical enamel margins compared to the control direct RC fillings. In the cervical enamel the open sandwich restoration showed a 97% and in the dentin an 87% gap-free interfacial adaptation. The frequencies for the direct filling were 73% and 64%, respectively. A clinical follow-up, which is on-going, may show whether there will be a clinically significant difference between the techniques in the long run. A Class II RC laminate restoration with a self-cured composite, studied with the same SEM analysing technique, showed in cervical enamel 89% and in dentin 84% gap-free interfacial adaptation (19). A three-step amphiphilic enamel-dentin bonding system was used in that study (Allbond 2; Bisco Inc, Itasca IL, USA) which has shown good clinical durability, while the self-etching primer used in the present study has only been tested longitudinally in Class III and Class V cavities (22, 32). Another reason can be differences in the way the light-curing of the RC was performed. In the above-mentioned study a special light-cone was used to cure the first cervical layer. It has earlier been shown that use of the light-cone reduced cervical contraction and gap formation (33, 34).

Use of a PMRC in the Class II laminate technique improved *in vitro* the marginal adaptation to dentin in the cervical area compared to bonded composite restorations, though the differences were not significant (30). The percentage of marginal openings found in the cervical area was very high; for sandwich restorations, 36%, and for the direct restorations, 87%. A better, but not significantly different, adaptation was shown with RMGIC compared to PMRC in the sandwich restoration. These results were not confirmed by Hannig et al. (16), who investigated *in vitro* an experimental PMRC in Class II dentin bordered cavities. They reported 94% excellent marginal integrity in enamel and 94% in dentin, suggesting that the technique offered an efficient method for achieving a load-resistant perfect marginal seal in Class II cavities. Dietschi & Herzfeld (24) investigated *in vitro* class II horizontally multilayered fillings after mechanical- and thermocycling. A 94% gap-free marginal enamel and 75% gap-free marginal dentin was reported. Gap-free internal dentin margins were found in 28–51% of the dentin interface. Because all the cavities in the present study were enamel-bordered, no conclusions can be drawn about the dentin-bordered cavity. Dijken van et al. (19) showed that the quality of *in vivo* interfacial adaptation decreased when the cervical margins of restorations were placed in dentin. In that study a sandwich restoration of self-curing and light-curing resin composite showed an interfacial quality equal to that of the open PMRC sandwich filling in the present investigation.

The simplified bonding approach of the self-etching primers is based on infiltration and modification of the smear layer by an acidic monomer. The concept of simultaneously infiltrating the collagen fibers while decalcifying the inorganic component to the same depth in dentin is attractive. This will minimize the risk of not reinforcing part of the demineralized dentine. Collapse of the collagen fibrils after conditioning and drying will also be prevented. The resin may infiltrate the smear layer and infiltrate the dentine slightly (0.1–0.5 μm) (35). A decreased etching effect on enamel has been reported and etching with phosphoric acid has therefore been recommended before application of the primer. In this study we therefore etched the Class II cavities with phosphoric acid before primer application. On the other hand, Hannig et al. (36) showed good marginal adaptation *in vitro* with 3 other self-etching primers in Class II cavities without the use of phosphoric acid conditioning. Andersson-Wenckert et al. (37) placed PMRC fillings *in vivo* in primary molars and used the self-etching primer only. They found a good interfacial adaptation quality with gap-free interfacial adaptation to enamel in 87% and to dentin in 84%. However, they found enamel fractures in 31% of the interfacial length investigated, indicating that the polymerization stress developed in the restorations probably discovered a weak link in the enamel surrounding the cavity. The frequency of enamel fractures found in this study was also high for the cervical enamel. These findings are in accordance with the marginal adaptation of PMRC to enamel observed in other *in vivo* studies (38), but do not support the findings of *in vitro* evaluations (39, 40). Laboratory studies showed higher bond strength to enamel after the use of enamel etching prior to the PMRC primer application, whereas Abate et al. (39) found no need for acid-etching of the dentin.

It can be concluded that the sandwich technique with the PMRC/RC can improve the interfacial adaptation to dentin and cervical enamel in enamel bordered Class II cavities *in vivo*. Clinical long-time evaluations must determine the clinical applicability of the sandwich restoration.

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