Voids and interlayer gaps in Class 1 posterior composite restorations: A comparison between a microlayer and a 2-layer technique

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Objective: The main objective was to compare the presence of interlayer gaps between 2 hybrid composites placed using a microlayer and a 2-layer technique. **Method and Materials:** Standardized Class 1 cavities were prepared in 40 extracted posterior teeth. Two resin composite materials were used. The control group, group A, consisted of samples of the materials extruded out of the manufacturers' syringes. Group B consisted of 10 teeth restored using 2 layers per restoration. Group C consisted of 30 teeth restored using 6 microlayers per restoration. A scanning electron microscope was used to detect voids in the samples. **Results:** Round, well-defined voids were found in 85% to 100% of the samples within the bulks of the resin composite materials only. A statistically significant relationship between the type of composite and presence of bubbles (Fisher exact test, $P = .04$) was found among the 2-layer technique group. No statistically significant difference (Fisher exact test, $P = .48$) was found among the microlayer technique group. Irregular interlayer gaps were found in 5% to 15% of specimens within areas between bulks of composite, as detected by an electron microscope based on the different densities of the bulks of composite and the interlayer areas. No such statistically significant relationship was found (Fisher exact, $P = .62$) among the study groups. **Conclusions:** Voids are routinely found in bulks of composite materials. Higher incidences of interlayer gaps in the 2-layer samples suggest that the use of a microlayering technique may result in fewer gaps.
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Key words: comparison, gap, microlayer, posterior composite restoration, technique, void

Posterior resin composite restorations have been accepted as a valid treatment option when a controlled clinical environment can be achieved.[1] Various clinical techniques have been published suggesting methods to overcome shrinkage problems and to achieve an improved marginal seal.[2–8] No statistically significant differences were found between these techniques when marginal seal characteristics were compared.[8,9]

Ideally, no voids or gaps should be present in the completed restoration.[9] A few studies that analyzed the size and number of porosities in completed direct composite restorations found voids larger than 1 mm in diameter.[8,9] Other authors found porosities in 84.6% to 100% of the analyzed samples.[3,5,9] Porosities were correlated with the thickness of the composite material, the placement technique, and operator skills.[5] Thinner/flowable composites tend to form fewer porosities within them when they are used as liners below hybrid or packable composite materials.[5] However, these

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flowable composites are not suitable as restorative materials for posterior teeth. Thus, it appears to be impossible to avoid porosities in direct composite restorations, even though their elimination is desirable.[9]

From an esthetic point of view, the use of only 1 shade of composite material cannot replicate the natural optical properties of dentin and enamel. To achieve the most life-like appearance, dentin shade composite materials are needed to restore the missing dentin tissues, and enamel shade composite materials are needed to restore the missing enamel tissues.[10,11] While achieving highly esthetic restorations, all techniques should be able to compensate for composite shrinkage.[2,3,6–8,12–14] This compensation can be achieved by using small volumes of material and by allowing these increments to touch either 1 or 2 "walls" (either enamel, dentin, or cured composite) during the curing process.[15] The use of highly viscous composite material (condensable/packable type) has been found to increase the risk of voids in restorations,[3,4,6,9,16] and the use of flowable composite materials does not completely eliminate the risk of voids or gaps.[9] For the purpose of this study it was hypothesized that using 6 micro-increments would introduce more unwanted interlayer gaps in the restoration.

The aims of the investigation were *(1)* to determine whether voids exist in unmanipulated hybrid composite materials (controls), *(2)* to compare the presence of interlayer gaps in 2 hybrid composites placed using a microlayer technique, *(3)* to compare the size of voids in 2 hybrid composites placed using a microlayer versus a 2-layer technique, respectively, and *(4)* to compare the number of bubbles in the 2 hybrid composites placed using a 2-layer versus a microlayer technique, respectively.

METHOD AND MATERIALS

Teeth and preparations

Standardized Class 1 cavities were prepared in 40 extracted, nondehydrated, natural posterior teeth. Cone-shaped cavities (external diameter of 3 mm, internal diameter of 1.5 mm, and depth of 3 mm) were prepared using rhomboid diamond burs (811.31.033, Brasseler USA) in a high-speed handpiece with water spray. The cavities were cleansed using water spray. The teeth were divided into 2 groups and restored using 2 different techniques: a 2-layer technique and a micro-layer technique developed for this study. One operator prepared and restored all cavities.

Materials

Two different bonding systems and composite materials were evaluated. Enamel Plus HFO hybrid composite material (Micerium) was used with Clearfil Bond SE (J. Morita USA), and Z100 hybrid composite material (3M Espe) was used with Single Bond (3M Espe). One syringe of each material and 1 set of each bonding agent were used for this study. Bonding techniques were used according to the manufacturers' instructions. All restorations were finished with Sof-Lex Finishing Brushes (3M Espe). A Demetron 401 light source (Demetron/Kerr) was used for curing. A scanning electron microscope (JSM-6400, JEOL USA) was used to detect voids in the samples.

Study groups

Group A, control: To evaluate the presence of voids within the composite materials themselves, samples of each of the materials used were checked. For each composite type, material was extruded out of the manufacturers' syringes and sectioned into 8 2-mm-thick bulks using a scalpel. Each bulk was cured for 40 seconds and subsequently sectioned both vertically and horizontally to form 4 segments. Two randomly selected, nonadjacent segments were scanned.

Group B, 2-layered restorations: Ten of the 40 prepared teeth were randomly selected. These teeth were randomly divided into 2 groups. Five of the teeth were restored using Clearfil Bond SE and Enamel Plus HFO composite material, and 5 were restored using Single Bond and Z100 composite material. After the bonding procedure, each cavity in this group was restored using 2 layers of composite. The initial layer was placed so it filled half the depth of the cavity. A flat sur-

Fig 1 An example of one of the microlayers held by a periodontal probe.

Fig 2 An example of one of the restored teeth utilizing the microlayering technique. *(a)* The original tooth. *(b)* The 3 dentin microlayers in place. *(c)* Two of the 3 enamel microlayers in place. *(d)* The final restoration.

face was achieved using a 1-mm-diameter smooth amalgam condenser. A second layer was placed after curing of the initial one for 20 seconds, shaped to restore the anatomy of the tooth and cured again for 20 seconds.

Group C, microlayered restorations: The remaining 30 prepared teeth were divided randomly into 2 groups. Fifteen of the teeth were restored using Clearfil Bond SE and Enamel Plus HFO composite materials, and 15 were restored using Single Bond and Z100 composite materials. After the bonding procedure, each cavity in this group was restored using 6 microlayers of composite material. The microlayering technique developed for this study utilized minute increments (about 1 mm^3) of composite material (Fig 1). Each increment was handled with a periodontal probe and placed specifically in its designated area. The first microlayer was placed in the deepest portion of the cavity, in contact with only the floor and 1 vertical wall. Each layer was cured according to the manufacturer's instructions prior to placement of the next one. After curing, additional microlayers were placed, making sure that each microlayer was in contact with a dentin or enamel wall and a previously placed microlayer. After restoring the missing dentin, additional microlayers were placed to restore the natural anatomy of the tooth (Fig 2).

Electron microscope analysis

After the restorations were finished, all teeth and composite bulks (control group samples) were embedded in transparent mounting medium (Electron Microscopy Sciences). Samples were cut using a low-speed diamond saw (Isomet, Buehler) in increments of 100 μm longitudinal thickness (coronoapical). Four of the 30 teeth in group C (2 from the Enamel Plus HFO subgroup and 2 from the Z100 subgroup) broke during preparation and were excluded from the study.

Because of the sample size, 2 unrelated samples of each tooth included in group A, 4 samples of each tooth in group B, and 2 unrelated samples from each bulk in group C were randomly chosen for examination. A scanning electron microscope was used for analysis. A 36× magnification allowed visualization of the entire composite restoration.

To ensure the ability to distinguish between the bulk of composite material and the interlayer area, V-shaped cuts were made on tooth dentin, continuous with the interlayer area of each of the 2-layer group samples. This allowed a physical mark that was easily detectable by the electron microscope. The electron microscope was able to detect the difference in density between the bulk of composite and the interlayer area, viewed as a darker line (Fig 3).

ed. One gap (7.7%) was found in the Z100 group (Fig 4), and one gap (7.7%) was found in the Enamel Plus HFO group.

Each sample was assigned a maximum bubble size score. Descriptive statistics of these scores by composite type and placement technique are shown in Table 1. The Kruskal-Wallis test revealed that the distributions of maximum bubble size scores were not equal across the 4 exposure groups ($P <$ .001). Dunn multiple comparisons tests showed the Z100 and HFO 2-layer samples to differ from one another ($P <$ .001). All other pairwise comparisons did not reveal any statistically significant differences.

There was no statistically significant relationship between the distribution of the number of bubbles and the 4 composite-technique exposure groups. Descriptive statistics for each of the groups may be found in Tables 1 and 2. The Kruskal-Wallis test did not reveal a statistically significant difference in the distribution of the number of bubbles among the 4 groups ($P =$ .39).

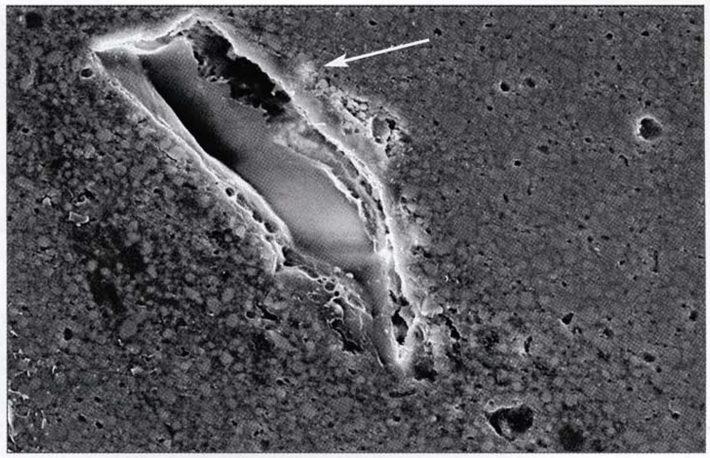

Fig 4 An electron microscope image showing an interlayer gap *(arrow)*. The gap measured 50 × 10 microns.

DISCUSSION

Esthetic posterior composite restorations require the use of dentin and enamel shades to restore and mimic the missing dental tissues.[10,11] Light-curing materials require specific placement techniques to minimize shrinkage hazards.[2,3,6–8,12–14] The microlayering technique is based on the accepted principle of layering, but utilizes smaller increments. The use of very small bulks of material allows control of their placement, and the use of dentin and enamel shades achieves the desired restoration of these missing tissues. However, there is concern that the increased number of layers might cause a high incidence of gaps between these layers.

Different types of composite materials are available for posterior composite restorations. Previous in vitro studies[3,4,6,9,16] showed that the use of highly viscous composite material (condensable/packable type) increased the risk of voids in the restoration. The use of flowable composite materials did not eliminate the risk of voids or gaps.[9] These studies further showed that hybrid composite materials with thin consistency resulted in fewer voids than thick composite materials.[2,3,5,9] Because of these findings, conventional (neither packable nor flowable) hybrid composite materials were chosen for this study.

Current literature suggests that minimally sized preparations are indicated for posterior composites, which is why cone-shaped cavities were prepared in this study.[17,18]

In previous studies, voids were found in 86.4% to 100% of the examined samples. Voids inside a composite restoration were found to be a result of air trapped within the material itself, air trapped between layers, or mal-opposition between layers.[2,3,5,9] Because of the higher magnification used in this study, a higher occurrence of voids was expected, in comparison to previous studies. Our findings are consistent with previous results.

To evaluate the percentage of voids within a restoration, the presence of voids within the composite materials themselves was needed. The findings in the control group show that voids were present in 93.75% to 100% of the samples. All of these voids were round and well-defined within the bulk of the materials. These were considered the "gold standard" for voids within the composite bulks in the 2-layer and microlayer restoration samples. Although our findings show that voids were present in all Enamel Plus HFO sam-

Table 1 Description of size distribution of maximum bubble size score* in the 4 composite-technique exposure groups, among samples with bubbles

Exposure	N	Median	Minimum	25th percentile	75th percentile	Maximum
2-layer Z100	17	6	2	4	6	6
2-layer HFO	20	3	1	3	4	6
Microlayer Z100	11	6	3	4	6	6
Microlayer HFO	13	4	1	3	5	6

*Score: 1 = 1–25 μm, 2 = 26–50 μm, 3 = 51–75 μm, 4 = 76–100 μm, 5 = 100–125 μm, 6 = 126+ μm.

Table 2 Pairwise comparisons of size distribution of maximum bubble (score) among the composite-technique exposure groups, as obtained via Dunn test

	Two-layer Z100	Two-layer HFO	Microlayer Z100	Microlayer HFO
2-layer Z100	–			
2-layer HFO	$P < .001$*	–		
Microlayer Z100	$P > .05$	$P < .05$	–	
Microlayer HFO	$P > .05$	$P > .05$	$P > .05$*	–

Kruskal-Wallis test, $P < .001$.

ples, the percentage of voids in the Z100 control group was higher than that found in the restorations fabricated with this material. This may be explained by the larger size of the control group samples.

Under 1,500× magnification, ovoid and elongated voids were found only in interlayer areas, as determined by a lower EM density. Such ovoid and elongated voids were not observed within the bulk of composite material in any of the scanned samples. These were considered to be gaps, created during the placement of the composite material. Three explanations can be suggested regarding the statistical difference between the Z100 and HFO 2-layer samples: handling of larger or smaller bulks of composite, the different thickness of the materials, and the difference in sample size. These same explanations can also be used to explain why fewer interlayer gaps were found in the microlayer samples. Although the use of larger bulks may seem to be more efficient, the placement of minute bulks allows greater control, resulting in fewer interlayer gaps.

In the current study, only 1 practitioner performed all the restorations. Further studies will be needed to analyze interoperator variations.

CONCLUSIONS

Our findings are consistent with other studies that evaluated different techniques of posterior composite placement. They found bubbles in up to 100% of their examined samples, with maximum diameter greater than 1 mm. The maximum diameter of the bubbles found in the present study was 550 μm. Bubbles (round and well-defined voids) were also routinely found in samples of the non-manipulated materials as extruded from the original syringes. Gaps, as defined in this study, were found in fewer than 15% of the samples. A higher incidence of gaps was found in the 2-layer samples, suggesting that the use of a larger number of minute increments may result in fewer interlayer gaps. These results do not prove our hypothesis that a higher number of composite bulks within a restoration will result in a higher percentage of voids within the restoration.

Under the constraints of this study, the findings of higher incidences of interlayer gaps in the 2-layer samples suggest that the use of a microlayering technique may result in fewer gaps, and therefore it is a valid technique for composite placement.

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