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Microleakage in Class II Restorations: Open vs Closed Centripetal Build-up Technique

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Clinical Relevance

Use of the centripetal open-sandwich technique may allow for placement of a Class II resin composite restoration with better marginal adaptation, fewer voids and reduced microleakage than the closed sandwich technique.

SUMMARY

Purpose: This study evaluated whether a Class II restoration in a flowable resin composite has to be placed prior to (open-sandwich technique) or after (closed-sandwich technique) construction of the interproximal wall in the centripetal build-up technique in order to reduce microleakage. Methods and Materials: Thirty non-carious molars were selected and randomly divided into two groups (n=15). A standardized Class II preparation was made with the cervical margin 1 mm below the cementum-enamel junction. In Group 1, flowable resin composite was applied as a 1 mm base, remaining exposed at the cervical margin. In Group 2, the hybrid resin composite was applied to the interproximal wall, followed by a layer of flowable composite on the pulpal floor, away from the margins. The restorations were then subjected to 500 thermal cycles, each with a dwell time of 20 seconds at 5°C and 55°C. Adaptation at the cervical margin was evaluated by dye penetration and SEM analysis using the replica technique. The data were statistically analyzed using the Mann-Whitney U-test (p<0.05). Results: The centripetal open-sandwich technique led to significantly lower dye penetration than the centripetal closed-sandwich technique (p<0.001). Conclusion:

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Flowable resin composite placed under hybrid resin composites in Group 1 provided better marginal adaptation and fewer voids. However, neither Group 1 nor Group 2 was able to completely prevent microleakage.

INTRODUCTION

With the increasing demand for esthetic treatment options in restorative dentistry, an interest in longevity and reliability of resin composite restorations has grown. Resin composites represent the material most commonly used as an alternative to amalgam for Class II restorations. Resin composites have been employed for many years. While their wear resistance has been satisfactorily improved in recent years,[1] difficulties in achieving an adequate interfacial seal and a valid interproximal contact point can still limit the clinical success of resin composite Class II restorations.[2] Both adapting resin composite to cervical walls and adjusting interproximal contact points are often considered critical steps.[2-3] Hassan and others[4] and Bichacho[5] have proposed the centripetal build-up technique for placing posterior resin composite restorations. This technique replaces lost tooth structure from the periphery towards the center of the cavity, thereby achieving better marginal adaptation to the pulpal floor.[5] The authors of the current study suggest incremental insertion in combination with centripetal resin composite build-up, thus transforming a Class II into a Class I restoration. The use of thin metal matrix bands and wooden wedges eliminates the need for transparent matrix bands, which may lead to poor contact areas and anatomical proximal contours.[6]

Also, sectional metal matrices can be utilized, along with ring retainers that exert pressure, thus allowing for proper modeling of the proximal contacts. In addition, the thin proximal layer of resin composite can expect to achieve complete curing and, thus, develop adequate mechanical properties. The use of enamel shades for the first interproximal layer, followed by dentin shades, leads to predictable and satisfactory esthetic results. The layer subsequently placed on the pulpal floor is believed to eventually fill any voids present at the cervical margin. The ability of the centripetal build-up technique to improve the marginal seal has been confirmed by recent laboratory-based studies.[7-8]

A relevant factor for the clinical failure of posterior resin composite restorations is the stress generated at the tooth-restoration interface due to competition between the rigid bond and polymerization shrinkage.[9] This may compromise the quality of the seal primarily at the pulpal margins located below the enamel-cementum junction of Class II restorations. In the attempt to improve the marginal seal, many strategies have been proposed, such as applying a combination of materials and using different curing regimes.[10] The use of a flexible lining of flowable resin composite has been advised.[11] Flowable composites are microhybrid resins with a 60%-70% by weight load of filler particles ranging in size from 0.7 to 1.0 microns. *In vitro* studies have shown that such resin composites exhibit a substantially lower modulus of elasticity, which enables increased elastic deformation to absorb polymerization shrinkage stresses, thus minimizing open margins, especially at the cervical level.[12]

This laboratory study evaluated whether the flowable resin composite in a Class II resin composite restoration should be placed before (open-sandwich technique) or after (closed-sandwich technique) construction of the interproximal wall in the centripetal build-up technique. The quality of the marginal seal was evaluated with microleakage. SEM observations were also undertaken to verify the presence of marginal gaps, as well as to visualize the morphological aspects of the tooth-restoration interface. The null hypothesis was that there is no difference between the open and closed centripetal build-up technique with regard to microleakage at the gingival margin of a Class II resin composite restoration placed below the cementum-enamel junction.

METHODS AND MATERIALS

Specimen Preparation

Thirty caries-free, unrestored human molars were selected and stored in a 1% chloramine solution for up to three months. A standardized adhesive Class II preparation was made in the mesial and occlusal surface. The cervical margin of the interproximal box was placed 1 mm below the cementum-enamel junction. Occlusally, the tooth was reduced by 2 mm and the cavity was 3 mm wide. The proximal box was 4 mm wide bucco-lingually; whereas, the pulpal and axial walls measured to be 2 mm deep. The dimensions of the prepared cavities were checked with a Boley gauge. A ±0.3 mm tolerance in the measurements was considered acceptable for including the specimen in the trial. No bevels were added to any margin of the preparations.

The teeth were randomly divided into two groups of 15 specimens each. All the specimens were restored with the adhesive Bond Force (Tokuyama, Tokyo, Japan), the flowable resin composite Palfique Estelite LV (Tokuyama) and the hybrid all-purpose resin composite Estelite Sigma (Tokuyama). Chemical composition and batch numbers of the materials are summarized in Table 1. A Brenner metal matrix was used to create the interproximal wall.

In Group 1 (open-sandwich technique), the cavity was air-dried and the bonding agent was rubbed in for 20 seconds, air-dried and light-cured for 10 seconds. The flowable resin composite was applied as a 1-mm

Table 1: *Adhesive and Resin Composites Tested in This Study*

Material	Type	Composition
Bond Force (Tokuyama, Tokyo, Japan) Batch #4T10787	All-in-one self-etch adhesive	Phosphoric acid monomer, Bisphenol A di(2-hydroxy propoxy) dimethacrylate (Bis-GMA), Triethylene glycol dimethacrylate, 2-Hydroxyethyl methacrylate (HEMA), Camphorquinone, alcohol and purified water.
Estelite Sigma (Tokuyama, Tokyo, Japan) LOT W805	Microhybrid resin composite	0.2 μm SiO_2-ZrO_2 (spherical) composite filler (82wt%), methacrylate monomers Bis-GMA/TEGDMA Camphorquinone
Palfique Estelite LV (Tokuyama, Tokyo, Japan) LOT 312	Flowable resin composite	0.2 μm SiO_2-ZrO_2(spherical) composite filler (42wt%) methacrylate monomers Bis-GMA/TEGDMA Camphorquinone

thick base at the cervical margin according to the centripetal open-sandwich technique (Figure 1) and light-cured (LCU, 3M ESPE, Seefeld, Germany) for 20 seconds. Then, a 2-mm increment of hybrid resin composite, shade C2, was applied on the gingival wall of the proximal box and packed interproximally towards the metal matrix, causing the resin to climb upward strictly in contact with the inner surface of the matrix band. This increment was adapted and light-cured. Subsequent 2-mm thick layers were placed in horizontal increments toward the occlusal margin of the cavity.

In Group 2, wherein the centripetal closed-sandwich technique was followed (Figure 2), after the application of the same bonding agent, the interproximal wall was created using 1-mm thick increments of the hybrid resin composite singularly light-cured for 20 seconds. After creating the interproximal wall, a 1 mm layer of flowable composite was placed on the pulpal floor and light-cured. Then, subsequent 2-mm thick increments of hybrid resin composite were placed and light-cured. The same number of increments was used for the two techniques.

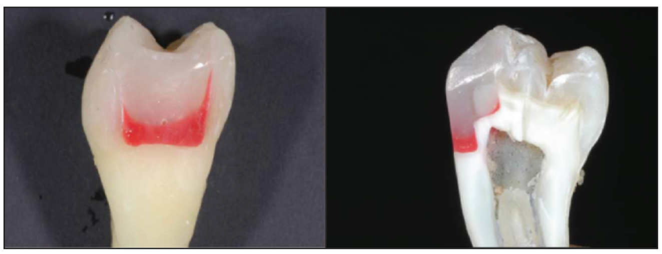

Figure 1: *Specimen restored with the centripetal open-sandwich technique: the flowable resin composite is demonstrated by the red area.*

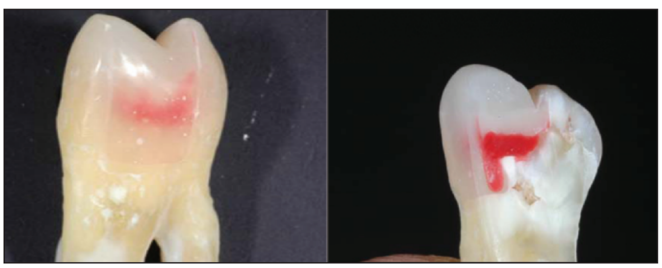

Figure 2: *Specimen restored with the centripetal closed-sandwich technique: the flowable resin composite is demonstrated by the red area.*

The restorations were then subjected to 500 thermal cycles, each with a dwell time of 20 seconds at 5C° and 55C°.

Impressions of the entire marginal area and interproximal walls were taken with a polyether impression material (Impregum, 3M ESPE) and epoxy resin replicas were cast (Epoxy Cure Resin, Buehler, IL, USA) for SEM marginal analysis. The specimens were mounted on aluminum stubs, coated with a colloid silver paint and sputtered with gold palladium (Edwards S105B Sputter Coater, London, England). The specimens were then observed under SEM (JEOL JSM-6060LV, Tokyo, Japan) to evaluate adaptation of the resin composites at the gingival margin with both techniques.

Dye Penetration Test

Nail varnish was applied to coat the foramina and the entire specimen surface, leaving a 1-mm window around the cavity margins. The teeth were then immersed in a 2% methylene blue solution for six hours. After rinsing the methylene blue solution off with distilled water, the specimens were embedded in acrylic resin and longitudinally sectioned with a diamond saw (Isomet, Buehler, IL, USA) at three different levels in the mesio-distal direction. The first cut was positioned in the center of the restorations, while the two remaining sections were cut along the lingual and buccal walls, approximately at the interface between the restoration and the cavity wall.

The extent of dye penetration at the cervical margin was assessed under an optical microscope (Nikon SMZ645, Nikon, Japan) at 25x magnification and scored as: 0 = no penetration; 1 = penetration not exceeding the middle of the cervical wall; 2 = penetration past the middle of the cervical wall; 3 = penetration along the axial wall.

Microleakage scores were independently assigned by two examiners and, in case of disagreement between

Table 2: *Microleakage at the Cervical Margin*

Group	N	Median	25th–75th Percentile	Significance $p<0.001$
1. Open sandwich	15	1	0–1	A
2. Closed sandwich	15	3	2.25–3	B

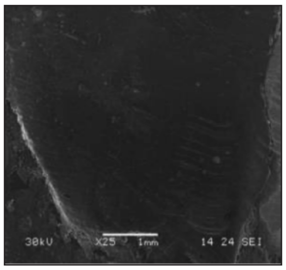

Figure 3: *Scanning electron micrograph of the tooth-restoration interface of a specimen restored with the open-sandwich technique.*

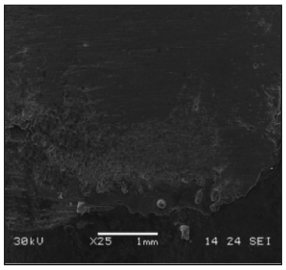

Figure 4: *Scanning electron micrograph of the tooth-restoration interface of a specimen restored with the closed-sandwich technique.*

their evaluations, the worse score was considered for statistical analysis.

Statistical Analysis

The Mann-Whitney U-test was applied to assess statistical significance of the difference in microleakage scores between the two experimental groups. The level of statistical significance was set at $p<0.05$.

RESULTS

Table 2 reports median values and the 25th-75th percentiles of microleakage scores recorded at the cervical margin in the two experimental groups, along with statistical significance of the between-group difference.

The Mann-Whitney U-test showed that the open-sandwich technique resulted in significantly lower microleakage than the closed-sandwich technique ($p<0.001$).

SEM observations at the gingival margins of Group 1 specimens (Figure 3) revealed adequate marginal adaptation without interfacial gaps or voids. The exposed flowable restorative material exhibited a smooth surface. Only slight overhang was present in one specimen, probably due to an inaccurate matrix placement. In the Group 2 specimens (Figure 4), marginal adaptation was less satisfactory and the surface of the hybrid resin composite appeared rough.

DISCUSSION

This *in vitro* study evaluated the sealing performance of two different incremental techniques for restoring Class II restorations with resin composite. The null hypothesis has to be rejected, as the open-sandwich technique demonstrated significantly less dye penetration than the closed-sandwich technique. This finding is in agreement with the outcome of a previous study, in which the closed-sandwich technique was reported to require greater operator skills and achieve poorer marginal adaptation.[13]

The current study moved away from the observation that clinicians routinely use flowable resin composite in the cervical margins of Class II resin restorations in association with the centripetal build-up technique as proposed by Bichacho.[5] The use of a relatively thick layer of a viscous bonding agent or a flowable resin composite has been advocated to absorb volumetric changes associated with polymerization.[11] It is assumed that a low-viscosity material can fill irregular margins of proximal boxes. Flowable composites are recommended as liners beneath Class II resin composite restorations due to their low viscosity, elasticity and wettability.[14] Additionally, these materials have a thermal expansion coefficient similar to tooth tissue.[15] Flowable composites exhibit a substantially lower modulus of elasticity that enables elastic deformation to absorb polymerization shrinkage stresses, reducing the tendency of open margins.[12] This ability seems to be most important when the gingival margin of a restoration is placed in the absence of enamel, where a less stable cementum-dentin substrate for bonding is present.[16-17] The majority of microleakage studies report greater dye tracer penetration in sites where the margin is in dentin, as compared with those located in enamel.[10,18] In this weak area, the open-sandwich technique probably permits a better seal with the use of flowable resin composite, as minimal stress is created at the cervical margin. In the literature, the use of a flowable resin composite at the gingival margin is claimed to reduce stress by 18%-50% and limit microleakage.[11,13]

Nevertheless, other studies assessing the clinical performance of posterior resin composite restorations placed with and without a flowable lining have reported no significant differences between the two procedures.[19-23] Therefore, further investigation of these clinically relevant issues are needed, taking post-operative sensitivity into consideration.

The SEM observations showed a better marginal adaptation and less cervical voids in open-sandwich technique specimens. This finding is in agreement with the outcome of other studies.[13,24] However, use of a flowable resin composite is to be restricted to areas free of occlusal contacts, such as cervical margins, due to the high wear rate of the material.[7,25]

The term microleakage and its clinical aspects were first defined by Kidd in 1976.[26] Microleakage studies can be realized as a part of an *in vitro* screening of new adhesive restorative materials, preliminarily to clinical testing. It should be pointed out that laboratory data provides less reliable evidence than *in vivo* trials. As a matter of fact, the contribution of microleakage to restoration failure remains controversial and the clinical relevance of interfacial dye penetration is still the object of discussion.[27] No operative technique or adhesive system has been proven to completely prevent microleakage and no correlation between gap width and tracer penetration was reported in a recent laboratory study.[28] Also, in the current study, in none of the specimens obtained with either restorative procedure was dye penetration completely impeded. Moreover, the methods of microleakage testing have not yet been standardized. A systematic review of microleakage tests for restorative materials concluded that a comparison of study results was impossible, due to the variability of the employed methodologies.[29]

As an example, different dye tracers are available for use in microleakage studies. Recently, Heitze and others reported that there is no significant difference in tracer penetration between fuchsin, silver nitrate and methylene blue.[30] Methylene blue is one of the most common tracers and can be used in different concentrations, from 0.5% up to 5%.[31] It was pointed out that, because of the small surface area of the particles (approximately 0.52 nm^2), methylene blue may lead to an overestimation of leakage at the tooth-restoration interface, particularly with self-etch adhesives in relation to their increased hydrophilicity.[32]

It is also disputed how many sections per tooth should be evaluated in dye penetration scoring. The evaluation of dye penetration scores is performed on one or more cuts of the specimen, and this method may be less sensitive than a three-dimensional evaluation.[33] However, it is believed that the use of three cuts of one specimen may avoid under-estimation of *in vitro* microleakage.[34]

Still another controversial issue is the dwelling time in the dye tracer. It has been reported that storage time in the tracer is not a relevant factor.[35] Conversely, another study documented that longer dwelling periods can lead to over-diffusion of the tracer and higher microleakage scores.[23] There is also no standardized protocol for thermocycling, as several different regimens have been proposed to simulate clinical function.[36]

In the current study, a new all-in-one self-etch dental adhesive that allows for simplification of the bonding procedure was used. Although etch-and-rinse three-step formulations are still regarded as the gold standard of adhesive systems, self-etch adhesives of the latest generation have given promising results both in laboratory and clinical studies.[37]

CONCLUSIONS

According to the methodology proposed and within the limitations of an *in vitro* study, the following conclusions can be drawn:

1. The centripetal open-sandwich technique produced a significantly more effective seal at the cervical margin of Class II resin composite restorations than the centripetal closed-sandwich technique, with better marginal adaptation and less voids.
2. Neither restorative procedure was able to fully prevent dye penetration.

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Erratum

In *Operative Dentistry,* 2010, **35-3**, 308-313, Microleakage in Class II Restorations: Open vs Closed Centripetal Build-up Technique, the correct order of the authors is: A Fabianelli, A Sgarr, C Goracci, A Cantoro, S Pollington & M Ferrari. This update has been posted online.

Also in *Operative Dentistry,* 2010, **35-3**, 353-361, Parameters Influencing Increase in Pulp Chamber Temperature with Light-curing Devices: Curing Lights and Pulpal Flow Rates, S-H Park, J-F Roulet & SD Heintze, Figures 1-3 have been updated online.