

Assessment of Microleakage in Class II Cavities having Gingival Wall in Cementum using Three Different Posterior Composites

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How to cite the article:

Narayana V, Ashwathanarayana S, Nadig G, Rudraswamy S, Doggalli N, Vijai S. Assessment of microleakage in class II cavities having gingival wall in cementum using three different posterior composites. J Int Oral Health 2014;6(4):35-41.

Abstract:

Background: Dental composites are one of the most desired restorative materials today. Composite materials can be bonded successfully to human tooth enamel; however, developing the same degree of adhesion to dentin or cementum is a more challenging task. Polymerization contraction stress of dental composites is often associated with marginal and interfacial failures of bonded restorations. The magnitude of stress depends on composite composition and its ability to flow before gelation, which is related to the cavity configuration and curing characteristics of the composite.

Materials and Methods: This study was carried out on 24 extracted human molars and divided into three groups. Class II (slot) cavities were prepared on the mesial and distal surfaces of the teeth with the gingival wall in dentin/cementum, and the microleakage was observed. After preparation the teeth were randomly assigned into three groups of eight specimens each. The cavities were restored with: Group 1: Packable composite (Surefil, Dentsply); Group 2: Hybrid composite (Filtek Z250, 3M Dental Products); Group 3: Nanocomposite (Filtek Z350, 3M Dental Products). Sixteen samples of each group were subjected to 500 cycles of thermocycling between 5°C and 55°C. All the teeth were immersed in methylene blue for 8 h and then left in tap water for 12 h. The teeth were sectioned mesiodistally with a diamond disc, and examined under a stereomicroscope.

Results: The analysis indicated that packable composite showed more microleakage than all the other groups. Hybrid composite showed less microleakage than packable composite, but more leakage than nanocomposite.

Conclusion: All composites under the study exhibited a certain amount of microleakage in the dentin/ cementum margin. Packable composite showed the most microleakage and nanocomposite showed least microleakage.

Since these results were obtained in vitro, long-term clinical trials are needed to fully understand the performance of these materials.

Key Words: Class II cavity, microleakage, gingival wall, posterior composites

Introduction

The restorative material which creates a permanent seal between the restoration margin and the tooth structure can be considered ideal. Today, posterior resin composites are popular owing to their esthetics, mercury free, thermal non-conductiveness and the micro-mechanical bond to tooth structure.

The bonding process is different for both enamel and dentin because dentin is more humid, more dynamic and more organic than enamel. Furthermore, Composite resin restorations are difficult because of the volumetric shrinkage that occurs when this material converts from monomer to polymer, a process named "polymerization."¹ Developments in filler technology and initiation systems have considerably improved the physical properties of composites and expanded their clinical applications.²

Due to the marked decrease in edentulousness in the older population, more of Class II and Class V lesions involving root structure occur. Failure is usually seen in adhesive resin restorations when restoring such cavities having cervical margins below the cemento-enamel junction (CEJ).^{3,4} The higher organic component, tubular structure, fluid pressure, and permeability along with lower surface energy of dentin make bonding of the composite to dentin more difficult than to enamel.⁵

The margins located below the CEJ are cervically limited by the cementum, which is different from dentin. The thickness of this outer layer may vary depending upon the site of the tooth. In the interproximal areas, the width of cementum is greater than that observed in the buccal or lingual areas. The presence and thickness of this outer layer of cementum may explain the

difficulty in achieving adhesion in these areas. Surprisingly, the cementum encountered in the margin has been largely ignored, and few studies in the literature have addressed the subject of cementum from a bonding point of view.³

In Class II composite restorations with the cervical margin below the CEJ, a gap usually forms along the cervical wall, which could be due to shrinkage of the composite during polymerization (of up to 2.0%) or from mismatches between either the coefficients of thermal expansion of the tooth and the composite or between the elastic moduli of the tooth and the composite. This leads to microleakage.⁶⁻⁸

In order to overcome the shrinkage stresses, several efforts were directed towards improving composite resin formulation, photocuring methods, and restorative placement techniques.⁶ Varying the filler particles, helps prevent microleakage, increases the modulus of elasticity and rigidity for the adhesive system. This means the filler size and content plays an important role in the clinical performance of adhesive systems.⁵ Composites that contain high filler levels have the best physical, chemical and mechanical properties but clinically, composites with small filler particles are easiest to finish. To combine the physical properties of larger particle systems and the polishability of microfill particles, hybrids were devised.⁹

In recent years, a new category of composites called nanofilled composites were developed. Nanocomposites offers high translucency, high polish and polish retention similar to that of microfilled composites, while maintaining physical properties and wear equivalent to several hybrid composites. Nanofillers permit overall filler levels of 90-95% by weight that will significantly reduce the effect of polymerization shrinkage and dramatically improve physical properties.⁹

Another approach used to reduce the polymerization rate by using an initial low-intensity curing light exposure, which would allow deformation to occur during the polymerization process and, consequently, decrease the tensile forces exerted by the hardening material.¹⁰

Polymerization contraction stress has been the subject of intense research activity over the last few years. With the increasing frequency of use of composites on posterior teeth with margins located on dentin, methods are needed that minimize leakage and provide patients with a more successful restoration.

Though most of the factors involved in stress development have been identified, further studies are necessary to assess the individual contributions of the composite's physical properties and curing kinetics and the potential interactions between them.²

Hence, this study is aimed at assessing the microleakage between tooth and restoration interface in a Class II composite restoration with the gingival wall in cementum using packable, hybrid, and nanocomposites.

Materials and Methods

Sample and storage medium

Freshly extracted human molars, extracted for periodontal reasons were collected from the Department of Oral and Maxillofacial Surgery, The Oxford Dental College, Bangalore. After extraction, the teeth were stored in distilled water until the test. The teeth were then scaled and examined under stereomicroscope for defects and microcracks, and 24 teeth were selected for the study.

Cavity preparation

Slot Class II cavities were prepared in both mesial and distal surfaces with a # 245 carbide bur in an air/water-cooled high speed turbine. A new bur was used for every five preparations to ensure cutting efficacy. Only one operator prepared the standard cavities. The bucco-lingual extension of the cavities was 3 mm. Axial walls were prepared to a standard depth of 1mm in dentin from the dentino-enamel junction. The gingival wall was located approximately 1.5 mm apical to the CEJ. The internal angles were rounded, and cavosurface margins were sharp without bevel and finished with gingival margin trimmers.

Restorative procedures

The prepared teeth were mounted in putty impression material (3M ESPE Dental Products) to simulate clinical conditions and supporting structures as closely as possible. The teeth were mounted three at a time to simulate proximal contact. Toffelmire metal matrix and retainer was used for each tooth. Wooden wedge was used to stabilize the matrix.

Teeth were randomly divided into three groups of eight teeth each (16 cavities).

The tooth structure is etched for 15 s with scotchbond multipurpose etchant (3M ESPE Dental Products), then 10 s water rinse, excess water was blotted using a cotton pellet. This was followed by the application of 2-coats of single bond 2 adhesive (3M ESPE Dental Products) for 15 s and gentle air dry. Light cured for 10 s.

Group 1: Shade 'A' of surefil packable composite (dentsply) resin was used to incrementally fill the cavities. Oblique increments of 2 mm were placed, each layer polymerized from the occlusal aspect for 40 s with the turbo-light emitting diode (LED).

Group 2: Shade 'A1' of Z250 Hybrid composite used (3M ESPE Dental Products) resin was used to incrementally fill the cavities. Oblique increments of 2 mm were placed, each layer polymerized from the occlusal aspect for 40 s with the turbo-LED.

Group 3: Shade 'A1' of Z350 nanocomposite used (3M ESPE Dental Products) resin was used to incrementally fill the cavities. Oblique increments of 2 mm were placed, each layer polymerized from the occlusal aspect for 40 s with the turbo-LED.

The output level increases from:

1-10 s – 120 mW/cm²

11-20 s – increases from 120 mW/cm² to 550 mW/cm²

21-40 s – 550 mW/cm²

A teflon coated composite filling instrument (Dentsply) was used to insert and condense the resin composite.

Finishing and polishing

Finishing and polishing were performed immediately after restoring. There was a minimal need for finishing, which was carried out using Sof-Lex disks (3M ESPE Dental Products). After polishing, specimens were removed from the impression material and stored for 1 week in distilled water at 37°C using a Bod incubator.

Thermocycling and microleakage test

The apex of each tooth was sealed with a self-curing acrylic resin and two coats of fingernail varnish used to coat all tooth structure except the restorations and 2 mm around them. All specimens were subjected to 500 thermocycles between 5°C and 55°C, with 30 s dwell time at each temperature with an exchange time of 13 s between baths. Specimens were immersed in 0.5% methylene blue for 8 h. After that, specimens remained in tap water for 12 h. All the specimens were sectioned longitudinally in a mesio-distal direction towards the center of the restorations using a diamond disc. A total of 48 sections was obtained. The specimens were analyzed under ×20 magnification in a stereomicroscope.

The degree of dye penetration was scored according to criteria described by FF Demarco *et al.*:¹¹

0 - No leakage.

1 - Leakage at the gingival wall.

2 - Leakage at the axial wall.

Results

Study design

A comparative study consisting of 48 samples is undertaken to investigate microleakage in packable composite, hybrid composite, and nanocomposite (Table 1).

Table 1: Comparison of three materials.

Leakage scores	0	1	2	Total
Packable composite (n=16)	0	9	7	16
Hybrid composite (n=16)	5	8	3	16
Nanocomposite (n=16)	7	7	2	16
Total	12	24	12	48

Test to find out if there is any significant difference between the leakages of three composites.

Level of significance: $\alpha = 0.05$

Statistical test used: Kruskal–Wallis test and Mann–Whitney test.

Decision criterion

P value is computed and compared with the level of significance. If $P < 0.05$, it could be concluded that there was a significant difference between the leakages of the composites. Otherwise, there was no significant difference between the leakage scores.

Computation

Table 2 gives the various computations and the *P* value.

Table 3 shows $P = 0.008$. Therefore, it was concluded that there was a significant difference in the leakages of the three groups ($P < 0.05$).

In order to find out among which composites there exist a significant difference with respect to the leakage scores, Mann–Whitney test was performed for each pair.

Inference

The difference in the leakage scores was statistically significant between packable composite and hybrid composite ($P < 0.05$). Furthermore, there was a significant difference in the leakage scores of packable composite and nanocomposite ($P < 0.05$). However, there was no significant difference in the leakage scores between hybrid composite and nanocomposite ($P > 0.05$) (Graph 1).

Discussion

Composite restorations have gained popularity over amalgam restorations due to esthetic demands and mercury hygiene. In the recent days, composites have undergone a tremendous amount of research and series of developments.

The microleakage process is a phenomenon of diffusion of

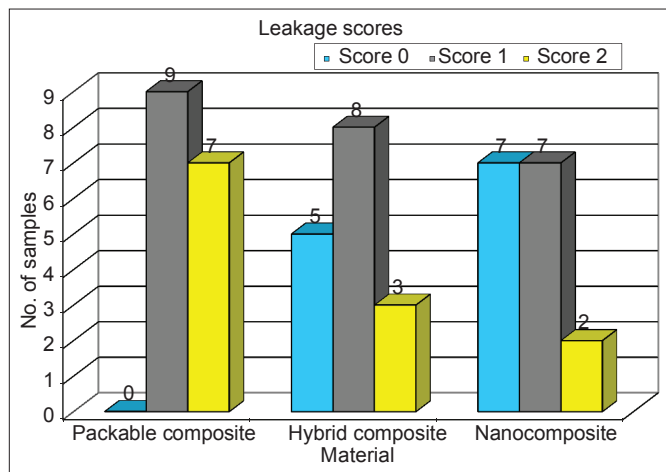
Table 2: Kruskal-Wallis test.

Score	Ranks		
	Group	N	Mean rank
Leakage score	Packable composite	16	32.38
	Hybrid composite	16	22.25
	Nano composite	16	18.88
	Total	48	

Table 3: Test statistics^{a, b}.

	Leakage score
Chi-square	9.547
Asymp. Sig	2.008

^aKruskal-Wallis test, ^bGrouping variable: Group



Graph 1: The leakage scores of packable, hybrid, nanocomposites.

substances, organic or inorganic; into the tooth through the interface between the restorative material and the tooth structure.⁹ Microleakage occurs due to dimensional changes in restorative materials such as polymerization shrinkage, difference in co-efficient of thermal expansion, hygroscopic expansion of materials and also due to extreme temperatures in the oral cavity, which may break the adhesion between adhesive system and cavity walls forming microgaps. This results in sensitivity, recurrent caries, possible pulpal pathosis, marginal deterioration, and discoloration. Some authors claim that the polymerization shrinkage of composite resins plays an important role on the debonding of the adhesive interface, consequently increasing the microleakage.¹²

Microleakage evaluation is the most common method of assessing the sealing efficiency of a restorative material.¹³ In general, microleakage has been evaluated using *in vitro* models, with dye penetration as the most frequently used method. This test presents some limitations, such as subjectivity of reading and high diffusability of dyes due to their small molecular weight. However, since new materials constantly appear, and considering clinical evaluations are time-consuming and expensive, *in vitro* methods for microleakage are important tools in evaluation of the possible performance of materials regarding sealing ability.¹⁴

The complex morphology of Class II cavities with margins partly in enamel and in dentin/cementum presents a challenging task for restorative material. The marginal seal can generally be preserved around cavity preparations when cavosurface margins are restricted to enamel due to its inorganic nature.^{15,16}

For dentin, on the other hand, the values of the internal stress are often larger than the bond strength to dentin walls and consequently a gap formation. The different coefficients of thermal expansion and young's modulus between composites

and tooth structure tend to exacerbate the interfacial gap, which leads to microleakage, the predominant reason for replacement of composite restorations.¹⁵

The cementum is a complex substrate. The cementum outer layer is hypomineralized and hyperorganic, which does not provide microretention for the adhesive materials even after acid-etching.¹²

The filler particles are added in order to improve the physical and mechanical properties of the organic matrix of composites, so incorporating as high a percentage as possible of filler is a fundamental aim. The filler reduces the thermal expansion coefficient and overall curing shrinkage, provides radio-opacity, improves handling and improves the aesthetic results.¹⁷

Nanotechnology has led to the development of a new composite resin characterised by containing nanoparticles measuring approximately 25 nm and nanoaggregates of approximately 75 nm, which are made up of zirconium/silica or nanosilica particles. The distribution of the filler (aggregates and nanoparticles) gives a high load, up to 79.5%. It should also be mentioned that the lower size of the particles leads to less curing shrinkage, creates less cusp wall deflection and reduces the presence of microfissures in the enamel edges, which are responsible for marginal leakage, colour changes, bacterial penetration and possible post-operative sensitivity.¹⁷

In this study, packable composite, hybrid composite and nanocomposite were examined for microleakage in Class II cavities were prepared with gingival wall in dentin/cementum.

In order to standardize the type of sample, maxillary and mandibular human molars were used for the study. The cavity dimensions were kept at a standard. The aging process used in this study was thermocycling. In order to generate tension levels at the interface between the restorative material and the dental structure, the restorations were thermocycled. This could have an influential meaning on the microleakage evaluation.¹⁸

de Almeida *et al.* stated that methylene blue enabled easy visualization of the prepared cavity. The dye also provides an excellent contrast with the surrounding environment.¹⁹

It has been suggested that an oblique incremental restorative technique could limit the effects of polymerization shrinkage at the cavosurface margins. Small increments with greater free surfaces in lieu of bonded ones would compensate for polymerization stresses rendering a better integration between the composite and tooth structure, thus resulting in a better-sealed restoration.¹³

A report by Neiva *et al.* has found that the incremental filling technique using a clear matrix and reflective wedges demonstrated the worst result in Class II resin composite restoration when the cervical wall was in cementum.¹ The proximal contact is also more difficult to obtain using clear matrix. Hence, metal matrix and wooden wedges were used for this study. The reports of Hilton, Schwartz and Ferracane have also indicated that microleakage is similar between clear and metal matrix.^{11,15}

Dentin bonding system used was single bond 2 for both the groups. It employs a two step total-etch technique. Poskus *et al.* has shown in a study that, a all-in-one self-etching adhesive system performed similar to total etch technique using 37% phosphoric acid in Class II cavities with cervical margins in the root dentin.²⁰

Single bond is a water/alcohol based system. Water-containing systems when applied to air dried, shrunken dentin plasticize the collapsed collagen by their water content, which may gradually be expanded again at the same time that resin monomers infiltrate. In addition, single bond is an adhesive that takes the advantage of the polyalkenoic acid copolymer derived from the glass ionomer chemical bonding concept. The polyalkenoic acid copolymer has been reported to form Ca-polyalkenoate complexes at the superficial 3 mm of the dentinal tubules. These complexes might stabilize the bonded interface by providing water stability and a stress relaxing effect.^{21,22}

A turbo-LED (Accordis Health Care, Italy) was used in this study. A slower polymerization allows a flow compensation of the resin mass during the contraction. Many studies have demonstrated that even with the light-cured composites, a slower polymerization of the first increment results in a well-adapted restoration, a technique called “soft-start” polymerization. The porosities reduce the relation between the adhering/non-adhering surfaces (C factor) because the oxygen present in the porosities impairs the polymerization of the resin that contacts it so that this subpolymerized mass could flow around and compensate for the contraction with less stress. However, these mechanisms were not sufficient to avoid the formation of gaps in this study mainly at the cementum margins.¹⁰

The resin composite materials used in this study had some degree of leakage.

Within this study, it was observed that packable composite (Surefil) showed the most microleakage among all the groups. This could be because packable composites need greater forces to condense material into the cavity preparation. The stiffest material showed greatest microleakage at gingival margins. Surefil has an average particle size of 0.8 μm , with some particles as large as 6 μm . the filler content is 65% by volume and is composed of barium fluoroaluminoborosilicate

glasses and fumed silica. Choi *et al.* and Chen *et al.* have shown that packable resins present a greater force of polymerization shrinkage compared with the following hybrid.^{23,24}

Hybrid composite (Filtek Z250) showed less microleakage than Packable (Surefil) composite (Figure 1). This may be due to the better adaptability of hybrid composite than packable composite.²⁵ The particle size distribution of Z250 restorative is 0.01 to 3.5 μm with an average particle size is 0.6 μm . The inorganic filler loading is 60% by volume. This smaller particle size of hybrid could also have been responsible for lesser leakage.

Hybrid composite showed more leakage than nanocomposite. However, it was not statistically significant. This could be due to the increased filler content of nanocomposite than hybrid composite.

Nanocomposite (Filtek Z350) showed the least microleakage (Figure 2). The filler contains a combination of a



Figure 1: Microleakage at tooth restoration interface using hybrid composite.

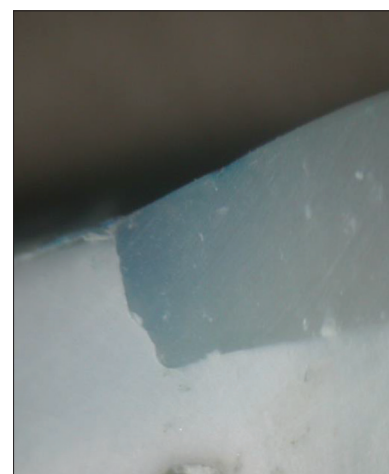


Figure 2: Microleakage at tooth restoration interface using nanocomposite.

non-agglomerated/non-aggregated, 20 nm nanosilica filler, and loosely bound agglomerated zirconia/silica nanocluster, consisting of agglomerates of primary zirconia/silica particles with the size of 5-20 nm fillers. The cluster particle size range is 0.6 to 1.4 microns. The filler loading is 78.5% by weight. Hence, the decrease microleakage score can be attributed to the filler size, content and the better adaptability of the resin in this group.⁶

Conclusion

Within the limits of this study, the following conclusions were drawn:

All composites under the study exhibited a certain amount of microleakage in the dentin/cementum margin. Packable composite showed the most microleakage among the three groups, hybrid composite showed less microleakage than packable composite but more microleakage than nanocomposite, however this increase in microleakage of hybrid composite over nanocomposite was not statistically significant. Nanocomposite showed less microleakage than both hybrid and packable composite.

In vitro studies have a tendency to overestimate the *in vivo* microleakage. However, techniques that consistently have bad results *in vitro* certainly do not deserve to be tested in clinical studies, which are much more expensive and arduous. Thus, laboratory studies allow a pre-selection of the techniques that deserve to be tested in our patients. This is our responsibility-to incessantly search for a technique that eliminates, or at least reduces, the microleakage to a minimum.

Since these results were obtained *in vitro*, long-term clinical trials are needed to fully understand the performance of these materials.

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