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Microleakage of Nanofilled Composite Resin Restorative Material

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ABSTRACT

The role of nanofillers in reducing the microleakage of dental composite resins has not been previously investigated. So this study was designed to evaluate microleakage of nanofilled composite resin in comparison to the conventional hybrid composite. Twenty extracted sound molars were selected. Class II cavities were prepared. All cavities were etched (enamel and dentin) with 37% phosphoric acid. Dentin bonding agents were applied to etched tooth surfaces and restored with nanofilled and hybrid composite restorative materials. The restored teeth were thermocycled. Specimens were immersed in 2% methylene blue dye, sectioned along the mesio-distal direction; dye penetration of occlusal and gingival margins of each section was evaluated using a stereo-microscope. No significant difference was found between the microleakage of nanofilled and hybrid composite restorations at occlusal/enamel and at gingival/dentin margins. Also, there were no significant differences for nanofilled composite restorations at occlusal/enamel margins and gingival/dentin margins. On the other hand, there were a significant differences for hybrid composite restorations at occlusal/enamel margins and gingival/dentin margins.

Keywords**:** *Microleakage*, *Nanofilled Composite Resin*, *Hybrid Composite Resin*

1. Introduction

Resin composites are increasingly used for restorative purposes because of good esthetic and the capability of establishing a bond to enamel and dentin [1]. However, like all dental materials, composites have their own limitations, such as the gap formation caused by polymerization contraction during setting, leading to marginal discoloration and leakage [2]. Improvements of mechanical properties of the composite have permitted its use in posterior teeth with greater reliability than was the case some years ago. This improvement included; development of smaller particle sizes of filler, better bonding systems, curing refinements and sealing systems [3].

Composite resin materials have progressed from macrofills to microfills and from hybrids to microhybrids, and new materials such as packable and nanofilled composites have been introduced to the dental market [4,5]. Each type of composite resin has certain advantages and limitations. The universal hybrid composites provide the best general blend of good material properties and clinical performance for routine anterior and posterior restorations [6]. A new brand of composite resins called nanofilled composites has been introduced to the dental market, which has been produced with nanofiller technology and formulated with nanomer and nanocluster filler particles. Nanomers are discrete nanoagglomerated particles of 20 - 75 nm in size, and nanoclusters are loosely bound agglomerates of nano-sized particles. The combination of nanomer-sized particles and nanocluster formulations reduces the interstitial spacing of the filler particles and, therefore, provides increased filler loading, better physical properties, and improved polish retention [3].

This investigation was designed to evaluate enamel and dentin microleakage of a nanofilled composite resin in comparison with conventional hybrid composite restorative materials.

2. Materials and Methods

The materials used in this study are presented in **Table 1**. A total of 20 specimens were prepared from both nanofilled and conventional hybrid composite resins. Specimens were cured with a light curing device (Chromalux E, Germany) according to the manufacturer's instructions.

Twenty freshly extracted sound (non-carious and non-restored) mandibular human molars were selected and

Table 1. Materials used in this study.

Materials	Type	Composition	Batch/lot No.	Manufacturer
Filtek^{TM} Supreme	Light curing nanofilled Composite Resin	Monomer matrix contains Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate and bis-EMA resin. Inorganic filler particles are a combination of aggregated zirconia/silica cluster and a non-agglomerated/non- aggregated silica filler.	3910A3.5B	3M ESPE Dental Products St. Paul, MN 55144
Prime-Dent®	Visible light cured hybrid composite resin	It is based on BIS-GMA resin and inorganic filler particles with average diameter of 1.40 microns	MB010	Prime Dental Manufacturing INC. 3735 W. Belmont Ave. Chicago, IL. 60618
Aper^{TM} Single Bond2 Adhesive	Light curing Bonding agent	Adhesive containing 10%, 5 nm colloidal filler	4BK51202	3M ESPE Dental Products St. Paul, MN 55144
SDI Super Etch	Etchant Gel	37% wt phosphoric acid	00601	SDI

cleaned, polished using scalars and pumice, and were stored in distilled water until being used. Class II cavities were prepared with a number 836 cylindrical diamond bur (Diatech diamond AG, Swiss). The cavities were prepared following a standardized pattern in which class II cavity had a length of 3.0 mm, width of 2.0 mm, and depth of 2.0 mm occlusally. The proximal box had an axial depth of 1.5 mm and buccolingual width of 4.0 mm. The cervical margin of the proximal box was located 1.0 mm below the CEJ [7]. The specimens were then randomly divided into two experimental groups, with 10 teeth each. All cavities were etched (enamel and dentin) with 37% phosphoric acid for 15 seconds according to the manufacturer's instructions, rinsed with air/water spray for 20 seconds followed by gentle drying for 5 seconds. Dentin bonding agent was applied to the etched tooth surface. Adper^{TM} Single Bond 2 Adhesive was applied to group a_1 and Prime- Dent® was applied group a_2. The teeth were then restored with Filtek Supreme (group a1) and Prime-Dent® (group a2). The resin-based composites were placed incrementally in three layers, and each layer was cured for 40 seconds from the occlusal direction according to the manufacturer's instructions for cavity class II compound. After the last increment was placed, the matrix band was removed. The restoration was also light-cured for 40 seconds from both the buccal and lingual walls according to the manufacturer's instructions [7].

The restored teeth were stored for 24 hours in distilled water, and thermocycled for 2500 cycles between 5˚C and 55˚C with a dwell time of 30 seconds in each bath [8]. The apices of the specimens were sealed with sticky wax, and all tooth surfaces were covered with two coats of clear nail polish with exception of 1.0 mm around the tooth-restoration margins and allowed to air dry. Specimens were then immersed in 2% methylene blue dye. The teeth were sectioned along the mesio-distal direction, coincident with the center of the restoration, with a sectioning diamond disc under water spray from chip syringe. The dye penetration of the occlusal and gingival margins of each section was evaluated independently by the observers using a stereo-microscope (Olymbus SZ 60, Japan) at a magnification of X 10 and scored as follow [7]: 0-No dye penetration; 1-Dye penetrations up to but not beyond 1/2 the occlusal or gingival wall; 2-Dye penetration up to but not contacting the axial wall.

3. Statistical Analysis

The data obtained were tabulated for statistical analysis which was conducted using SPSS (Statistical Package for Social Science) version 10. Chi-Square test was used to detect the significant differences among the variables tested.

4. Results

The results of microleakage are presented in **Tables 2-5**. Chi-square test demonstrated no significant difference between the microleakage of nanofilled composite (Filtek Supreme) and hybrid composite (Prime-Dent) restorations at occlusal/enamel margins ($P > 0.05$) (**Table 2**). At the same time, there were no significant differences at gingival/dentin margins ($P > 0.05$) (**Table 3**).

There were no significant differences for nanofilled composite restorations at occlusal/enamel margins and gingival/dentin margins ($P > 0.05$) (**Table 4**). On the other hand, there were a significant differences for hybrid composite restorations at occlusal/enamel margins and gingival/dentin margins ($P \leq 0.01$) (**Table 5**).

5. Discussion

Microleakage is defined as dynamic clinically undetectable passage of bacteria, fluids, chemical substances, molecules and ions between the cavity walls and the restorative material applied. Microleakage is used as a

Table 2. Chi-square (x^2) and leakage score values of test materials in occlusal/enamel margins.

Materials	Leakage Scores				Chi-Square (x^2)	P-value
Scores	0	1	2	3		
Nanofilled composite (n = 10)	5	2	1	2	1.62	0.65
Hybrid composite (n = 10)	3	2	2	3		

Table 3. Chi-square (x^2) and leakage score values of test materials in gingival/dentin margins.

Materials	Leakage Scores				Chi-Square (x^2)	P-value
Scores	0	1	2	3		
Nanofilled composite (n = 10)	1	3	1	5	6.47	0.09
Hybrid composite (n = 10)	0	1	3	6		

Table 4. Chi-square (x^2) and leakage score values of nanofilled composite restorative materials in occlusal/enamel and gingival/dentin margins.

Materials	Leakage Scores				Chi-Square (x^2)	P-value
Scores	0	1	2	3		
Nanofilled composite (n = 10)	1	3	1	5	6.47	0.09
Hybrid composite (n = 10)	0	1	3	6		

Table 5. Chi-square (x^2) and leakage score values of hybrid composite restorative materials in occlusal/enamel and gingival/dentin margins.

Materials	Leakage Scores				Chi-Square (x^2)	P-value
Scores	0	1	2	3		
Nanofilled composite (n = 10)	3	2	2	3	6.47	0.09
Hybrid composite (n = 10)	0	1	3	6		

measure by which clinicians and researchers can predict the performance of restorative materials in the oral environment [9,10].

Microleakage is caused by polymerization shrinkage of composite restorative materials. High bond strength between the restoration and the dentin surface may resist the polymerization shrinkage of the restoration and subsequent microgap formation at the tooth-restoration interface [11]. Poor adaptation of the restorative materials to cavity walls and margins and the method by which the restorative material is inserted may affect the sealing properties of the restorative material [12,13]. Difference in coefficient of thermal expansion and contraction between tooth structure and the applied restorative material had been implicated in microleakage through marginal percolation or through disruption of the marginal enamel etch bond, allowing microleakage in the space resulting from thermal contraction [14]. It has also been found that the type of occlusion and masticatory forces have a marked effect on the development of marginal leakage in composite restorations. The frequency of marginal leakage was significantly greater in teeth that were in functional occlusion than in similar teeth without antagonist [14,15]. The oral environment is also of importance in determining the extent of marginal leakage, where both restoration and surrounding tooth substance are subjected to mechanical loading and temperature variations when become in contact with food, saliva and microorganisms [15,16].

Modulus of elasticity of the restorative material can also be considered one of the causes of marginal microleakage [17]. Therefore, the importance of applying an intermediary layer with a low elasticity module or a stress breaker layer. This layer would then provide enough flexibility to compensate the tension generated by polymerization shrinkage [18].

In clinical practice, three commonly encountered problems may be associated with microleakage in dental restorations. These problems are postoperative sensitivity [19], marginal percolation [14], secondary marginal caries [19]. The incremental placement technique in the restoration of Class II cavity preparations seems to improve the marginal seal of the proximal walls of finished restorations [20].

In this study dye penetration method was used to evaluate the microleakage because methylene blue dye penetration method provides the evaluators with a perfect and easy visualization of the prepared cavity in the digital images which provide the evaluators with a clear reference point from which to score. The dye also provides an excellent contrast with the surrounding environment [21].

All tested groups showed dye penetration at the tooth-restoration interface. This could be attributed to the dimensional changes of the resin material which often result from polymerization shrinkage of the restorative resin, and differences in coefficient of thermal expansion and contraction between the tooth and the restorative material. These changes in the material produce internal forces that results in gap formation at the tooth-restoration interface, which in turn causes microleakage [22].

The results of the present study showed that, the score of microleakage values was lower for nanofilled composite than hybrid composite in all groups, but the difference was not significant. The score of microleakage values was lower for two types of composite restorations at the occlusal margins than at the gingival margins placed below the cemento-enamel junction (CEJ) and the difference was significant for hybrid composite restorations, but was not significant for nanofilled composite restorations. These results could be attributed to the inadequate adaptation of resin composite restoration in posterior teeth caused by the great dentin/enamel proportion in the cervical area and the critical difference of the thermal expansion coefficient between the tooth and the restorative material which allowed tracing agent penetration [23-26].

In this study, gingival/dentin margins showed significantly higher leakage than occlusal/enamel margins in hybrid composite restorative materials. This was expected as the bond strength to enamel is usually higher than bond strength to dentin, as dentin is a less favorable bonding substrate and the heterogeneous structure of dentin also affects the quality of bonding of the current dentine bonding systems [27-31]. Also, the orientation of dentinal tubules can affect the formation of the hybrid layer. In areas with perpendicular tubule orientation, the hybrid layer was significantly thicker than areas with parallel tubule orientation. Therefore, the dentine surface on the gingival floor of class II preparations may be a surface on which good hybrid layer formation is difficult the fact that contributed to the results of the present study in which substantial leakage occurred [32]. In the present study, the absence of statistically significant differences between occlusal and gingival margins could attributed to the high and reliable dentin bond strength of the used adhesives. The gaps between restorative material and cavity walls generally occur when the bonding capacity of the adhesive systems is insufficient to resist the forces of polymerization shrinkage of the composites [33].

Clinically, there were many attempts to reduce microleakage around restorations. During cavity preparation, all surfaces should be smoothed, cleaned dried to achieve maximum adaptation of the restoration to the cavity walls. It has also been found that beveling of cavosurface margins would provide for an increase in marginal surfaces which in turn, would compensate for polymerization shrinkage to some extent [34-36]. Removal of smear layer by acid etching increase the permeability of dentin by exposing the orifices of dentinal tubules [37,38]. Increasing surface area for bonding by means of acid etching technique followed by application of direct adhesive was found to significantly reduce microleakage level [39-41]. Good adhesion of the restorative materials to tooth structure [9,35,37].

6. Conclusions

There was no significant difference among the tested materials regarding the microleakage.

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