A Microleakage evaluation of Sonicfill, Silorane-based and nanofill methacrylate-based composites (a comparative study)"

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Abstract

Introduction Resin composites have been improved greatly nowadays, and many advancement has been reached. However, polymerization shrinkage is still a challenging drawback of composite resin restorations. Objectives this study was conducted with aim of comparing, in vitro, the marginal adaptation of three different, low shrinkages, direct posterior composites. Materials and Methods The following composites, Sonic fill® (nanohybrid composite), Filtek® P90 (Silorane-based composite) and Filtek® Z350 (nanofill composite) utilizing a standardized Class V cavity preparation followed by thermal cycling. Sixty human premolars prepared with standardized Class V cavities. The specimens were divided into three groups (n=20) according to the material used. All specimens were subjected to thermocycling at (5° to 55°C), then immersed in 2% methylene blue dye for 24hrs. For each group microleakage at the occlusal and gingival regions was measured by determining dye penetration using scoring system under steromicroscope at 100x. Results The statistical analysis of the results showed that, silorane-based composite exhibited the lowest microleakage, with statistical significant difference (p< 0.05) when compared with Sonicfill® composite and Filtek® Z350 XT nanofill composite. On the other hand, the results of this study showed non-significant difference between Sonic fill® composite and Filtek® Z350 XT. Also, there is a significant difference ( < 0.01) in dye penetration between occlusal and gingival regions within each group. Conclusion Taking into consideration the types of composites tested in this study, we recommend the clinical use of Siloran-based composite material for higher microleakage resistance and better marginal seal.

Keywords: Composite, Micro leakage, Siloran-based.

Introduction Improvement in dental sciences has led to a great shift in the way teeth are restored today. Placement of direct composite restorations have increased due to the high demand for esthetic restorations, for it cosmetic dental procedures, conservation of tooth structure, all of which together, contributed dramatically to many advances in
the field of adhesive technology (Nadig et al. 2011). Microleakage is a common and critical problem associated with composite restorative materials. It can develop for one of the following reasons: as a result of polymerization shrinkage of composite resins (Kusgoz et al. 2011); incompatible between the thermal expansion coefficients of the tooth and composite; or the difference between the elastic moduli of the tooth and the restoration (Stockton and Tsang 2007). On top of this, the composition of the material, the plastic deformation, the coefficient of thermal expansion and the mechanical stress caused by the cavity shape can also influence on the material ability to seal the cavity margins (Korkmaz et al. 2007). For such a hermetic marginal seal has become main target for the clinician. Once the gap formation has occurred; it cannot be repaired without replacement of the entire filling materials with a new one to inhibit the demineralization over the cavity margins and recurrent caries regression (Roggendorf et al. 2011).

In 2002, the urge to develop new materials has led to a flowable low shrinkage nanofill composite called Filtek™ Z350 by 3M ESPE. Nanotechnology in the field of dentistry forces on the production of nanocomposites by improving the filler technology of submicron particle size, modification of organic matrices and silane coupling agents (Beun et al. 2007). The aim of such work is to improve the physical and mechanical properties of the composite restoratives. In addition, containing nano-size filler particles in the final formulation of the composites reduces the composite’s shrinkage and improve its total mechanical properties (Condon and Ferracane 2002). In 2007, a hydrophobic low-shrinkage (Ilie and Hickel 2006) composite material based on new resin chemistry with silorane monomers have been introduced by 3M ESPE (Filtek™ P90). This innovative resin matrix performs the main differently compared to the conventional methacrylates (Weinmann et al. 2005). Filtek™ P90 is a radiopaque light-curing silorane-based composite. It contains 55% volume (76% weight) inorganic fillers with a particle size between 0.1 and 2μm (Filtek™- p90). Sonic fill™ system (Kerr/Kavo) was introduced in the market in 2010. It’s a bulk fill posterior composite restoration and can be use up to 5mm in depth due to claimed reduction of polymerization shrinkage. Sonic fill™ contains a special modifier with highly-filled proprietary resin which reacts to the sonic energy (Ahmed 2013). As the sonic energy is applied by a special KaVo hand piece, the flow ability of the composite increases, causing the viscosity to drop up to 87%; which then allows for quick placement and accurate adaptation to the cavity walls. When the sonic energy stops, the composite returns to a high viscosity and non-slumping state for accurate carving and contouring (Eunice et al. 2012; Jackson 2011).

In spite of the development in the adhesive fields; a 100% perfect margin is unachievable (Nadig et al. 2011). For that reason, the aim of this study is to compare three developed composite materials for their microleakage performance in a class V cavity after challenging the different materials with thermal changes.

Materials and Methods

Sample selection
60 human premolars (upper and lower) were selected for the study and divided into 3 groups of 20 teeth each. Each tooth was freshly extracted, structurally sound, crack-free and had no anatomical anomalies (Gonzalez Lopez, et al. 2006). These teeth were extracted from subjects within the ages of fifteen and twenty-five years old as a part of an orthodontic treatment plan.
As previously described by Ghulman and others (Ghulman 2011; Magne and Oganesyan 2009), the teeth were thoroughly cleaned with a hand scaler, polished with pumice, and washed with distilled water. Finally, samples were stored in distilled water at room temperature during all of the stages of the study to prevent dehydration. Samples included in this study were not stored longer than two months, in order to prevent decalcification (Borges et al. 2012). The samples were verified for minimal dimensional variability, as specified in previous work (de Paula et al. 2008). The teeth were evenly divided into three groups of twenty teeth each (n=20) according to the type of composite used to restore the cavities; Sonicfill™ Composite, Filtek™ P90 Silorane based composite, and Filtek™ Z350 XT, Nanofill composite.

**Teeth positioning**

To simulate the horizontal situation during cavity preparation, every four teeth were embedded in stone blocks leaving the buccal surface uncovered. Stone is mixed and poured to obtain stone blocks were mixed using a rubber bowl and spatula and poured in a plastic mold; the teeth were then embedded in the horizontal situation. After setting, the mold was mounted to the modified dental surveyor (Dentaurum, Germany) for cavity preparation.

**Cavity preparation**

With the aid of a dental surveyor, standardized class V cavities were prepared at the buccal surface of each tooth 1mm occlusal to the cemento-enamel-junction (CEJ). This was carried to assure that cavosurface line angles were prepared within the enamel. All cavities were in the buccal surface with a dimension of 4mm in width (mesio-distal), 2mm in height (occluso-gingival), and 2mm in depth using a diamond flat end fissure bur (HoricoDiament, Germany). The width and height was determined using a point Vernier caliper then pointed using a marker. The initial entrance was made by utilizing a round bur then the depth was obtained by a diamond flat end fissure bur in a high-speed handpiece (W&H, Austria) mounted on the vertical arm of a dental surveyor, with copious amount of water spray. The diamond fissure bur was marked with a nail varnished to 2mm from its end to ensure a definite 2mm preparation depth. A new bur was used for each five preparations. Non-beveled butt joint cavosurface line angles were prepared all around using a stainless steel fissure bur mounted on low-speed handpiece (NSK, Japan) in order to avoid the risk of reducing or entirely removing the thin enamel layer cervically.

**Restorative Procedure**

Each composite system was used according to the manufacturer’s instructions with their corresponding adhesive systems. Shade A3 was used for each corresponding composite type. For Group A (Sonicfill™ posterior composite unidose capsules, shade A3, Lot No. 5028476, Exp.Date: 2015-11 Kerr, USA), the entire cavity was conditioned for 30 seconds with 35% phosphoric acid gel (ultradent, USA) and washed immediately with an air/water jet for 30 seconds. Dryness of the dentin was obtained using gentle air jet for 30 second. Then, the bonding system (ultradent, USA) was applied to the entire surfaces of the cavity using a light brushing motion, dried with gentle air flow, and light cured for 10 seconds. Afterwards, the Sonic fill™ composite was placed using activated Sonic fill™ handpiece at medium speed. After the handpiece activation, Sonic
fill™ composite was placed in the cavity in a single, bulk increment then cured for 20 seconds at intensity of 800 mW/cm² using a LED light curing device (WoodPecker, Model LDE.C, China).

Group B (Filtek™ P90, silorane-based composite, shade A3, Lot No. N496908, Exp. Date: 2014-11, 3M ESPE, USA), comes with a specially developed adhesive system (3M ESPE AG, Germany) which consists of a self-etch primer and a bond. The primer was applied to the entire cavity surfaces with a disposable brush for 15 seconds then air dried gently, and light cured for 10 seconds by a LED light curing device. Then the bond was applied to the entire cavity surface with a disposable brush, air dried gently, and light cured for 10 seconds as for the primer. Then Filtek™ P90 composite resin was applied to the cavity in a single increment with a plastic instrument and was light cured for 40 seconds.

For Group C, using Filtek™ Z350 XT (Nanofill methacrylate-based posterior composite, shade A3, Lot No. N461049, Exp. Date: 2015-09, 3M ESPE, USA). The entire cavity-surfaces were conditioned for 30 seconds with 35% phosphoric acid gel, wash immediately with an air/water jet for 30 seconds. Then, the Bond was applied to the entire cavity surfaces using a light brushing motion, dried with gentle air flow and light cured for 10 seconds (as Group A had been). After completing the adhesive procedure, Filtek™ Z350 XT composite resins were applied as a single increment and light curing for 20 seconds.

For all teeth specimen of the three groups, a Celluloid strip was applied to minimize the finishing steps, and to ensure the adaptation of composite to the cavity walls. After completing the restorative procedure, a wheel shaped finishing bur was used to remove excess composite and for finishing.

**Thermocycling**
Specimen were stored in distilled water at 37°C for one week and then went through thermocycling (LTC 100 thermocycler, LAM Technologies) in order simulate temperature changes in oral cavity. The teeth were exposed to two different water baths: one maintained at 5°C and the other at 55°C, with a dwell time of 30 seconds. There were 500 cycles assuming ten cycles of hot and cold drinking per day (Loguercio et al. 2004; Pazinatto et al. 2003).

**Dye Penetration Test and Sectioning**
After thermocycling, the teeth have been dried and their apices were blocked with sticky wax to prevent dye penetration through the apical foramen. Afterwards, the teeth were coated with two layers of nail varnish within approximately 2mm of the tooth/restoration interface except gingivally (1mm), in order to prevent dye penetration in areas other than tooth/restoration interface. The teeth were then immersed in 2% methylene blue dye (Sparks, USA) for 24 hours at room temperature. After dye penetration, the teeth were rinsed under running water and dried. Afterward, they were sectioned longitudinally (bucco-lingually) through the cusps> tips using a microtome sectioning machine (MTI Coprporation, Ritchmond CA) with a water cooling system.

**Microleakage Measurement**
Microleakage was evaluated by assessing the linear dye penetration at the tooth/restoration interface occlusally; and gingivally, this was done using the stereomicroscope
at 100x magnification, according to the scoring system used by RadhiKaet al. (M et al. 2010) which is briefly described below:
-Score 0 = no dye penetration.
-Score 1 = dye penetration into enamel.
-Score 2 = dye penetration beyond the dentino-enamel junction.
-Score 3 = dye penetration into the axial wall.
Scoring were recorded the occlusal and gingival reading from each specimen.

Statistical analyses
The IBM statistical software package SPSS 20 was used to perform the Kruskal-Wallis test for independent non-parametrical data. This was followed-up by Mann-Whitney U test for each base-pair comparison. Results were considered statistically significance if there was p value <0.05.

Results
Over all, our results indicate that the Siloran-based composite performed the best in comparison to the other two groups (Figure 1). Specifically, Siloran was significantly less prone to microleakage in the gingival wall (Figure 2A), occlusal wall (Figure 2B) according to the statistical analysis. Noticeably, all type of composite tested in this study showed less microleakage in the occlusal side of the cavities, as compared to the gingival area Figure 3.

Figure 1. Microleakage score was recorded after thermocycling (500 cycles at 5°-55°C) and 24 hrs. of methylene-blue-dye penetration challenge of the three different composite. Cumulative score, (p at least <0.05).
Figure 2: Microleakage score of thermocycling at (5°-55°C) and 24 hrs. of methylene blue dye penetration challenge of the three different composite. A) Gingival score, and B) Occlusal score analyses. (p at least <0.05).

Figure 3: Dye penetration (microleakage score) was compared occlusally and gingivally, within each group. Bars donated with the same letter mean statistically significant different, (p at least <0.05).
Discussion

Microleakages is one of the critical challenges in aesthetic dentistry. The development of materials with a low level of microleakage is the utmost importance to all dental material companies. Here in our study, we have challenged three newly developed materials and our results shows that Siloran-based materials did perform better than all of the other tested materials. This could be attributed to the difference in chemical composition of the matrix system, the inherent ring-opening polymerization of oxirane moieties in the silorane monomer of Filtek™ P90 composite resin starts with the cleavage and opening of the ring mechanism which helps in gaining space and counteracts the loss of volume which occurs in the subsequent steps, when the chemical bonds are formed manifested as a reduction in polymerization shrinkage stress at the tooth/restoration interface as compared to the linear polymerization of the methacrylate-based composite resins (Parolia et al. 2014).

It is also hypothesized that since silorane technology provides lower polymerization shrinkage and related polymerization stress than methacrylate-based composite resins, it should be able to withstand thermocycling fatigue at the tooth/restoration interface better than the methacrylate-based composite resins (Al-Boni and Raja 2010; Soldo et al. 2013).

Additionally, by the method of micro-Raman spectroscopy, it has been confirmed that the hybrid-layer, created by the silorane adhesive system, is of a comparable thickness to that created by the methacrylate-based adhesives (Soldo et al. 2013).

The decreased polymerization kinetics of the oxirane compared with the methacrylate-based monomers generated a temporary excess of free volume that enhanced the mobility of the polymer chains within the system. As a result, the polymerization efficiency of the cationic ring-opening monomers was increased as compared with the free radical species contained within conventional methacrylate-based resin (Bogra et al. 2012). Furthermore, the lower magnitudes of water solubility of silorane based than methacrylate-based resin composites, due to presence of hydrophobic siloxane and quartz filler may make the silorane more stable to leach into water than those with metallo-silica glasses (Leprince et al. 2010; Parolia et al. 2014; Santos et al. 2013).

From all these findings it is proven that the silorane-based composite has been associated with less microleakage when compared to methacrylate-based composite materials. The findings of this study come in agreement with the many other studies, in which reported that the silorane-based posterior composite showed significantly less microleakage than the methacrylate-based composite (Krifka et al. 2012; Parolia et al. 2014; Santos et al. 2013; Soldo et al. 2013).

In addition, the results in this study showed that there is statistical significant difference (p<0.01) in dye penetration between occlusal and gingival regions for all groups, it showed that the occlusal regions for all groups had less microleakage as compared with the gingival regions. This could be attributed to lesser thickness of enamel at the cervical area and lesser enamel/dentine ratio. The dentine margins showed inferior quality of bond interface, indicated by a significantly higher microleakage than the enamel. The probable reason for this was that the bond strength to enamel is usually higher than to dentine. Dentine is less favorable bonding substrate due to its heterogeneous structure. On the other hand, Enamel is a highly mineralized tissue composed of more than 90% of hydroxyapatite, whereas, dentine contains a substantial proportion of water and organic material primarily type I collagen. This increased
in microleakage could be due to thermocycling, composite restorations exhibited an increase in microleakage at cervical margin when exposed to thermal changes. In a study of Paula et al. in 2008 (de Paula et al. 2008) found that the thermal cycling negatively influenced marginal adaptation, regardless of the restorative technique, with a significant increase in the percentage of marginal gaps, especially at the cervical areas. Other researcher has also supported our findings that cervical microleakage are likely to occur than occlusal (Erdilek et al. 2009; Simi and Suprabha 2011).

Conclusion
Taking into consideration the types of composites tested in this study, we recommend the clinical use of Siloran-based composite material for higher microleakage resistance and better marginal seal.

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