THE EFFECT OF SURFACE PENETRATING SEALANTS ON LEAKAGE PATTERN OF CLASS V RESTORATIONS WITH DIFFERENT LOCATIONS OF CERVICAL CAVITY MARGINS

Hanem Hamed Ahmed; Eman Ismail Mahmoud Fath El-Bab and Mohsen Hussein Abi El-Hassan

ABSTRACT

The present investigation was designed to study the effect of two types of surface penetrating sealants on leakage pattern of class V resin composite and resin modified glass ionomer restorations with different locations of cervical cavity margins (enamel and cementum) whether thermocycled or not. A total of 120 sound human upper premolars were divided into two equal groups (60 premolars each) relative to restorative material used whether resin composite or resin modified glass ionomer. Each group was further subdivided into three subgroups (20 premolars each) relative to type of surface penetrating sealant used. In the first subgroup, cavities were restored without surface sealant treatment (control group). In the other two subgroups, cavities were sealed with either pit/fissure sealant (Heleoseal clear) or specific surface penetrating sealant (Optiguard) respectively after their restorations. Each subgroup, was further subdivided into two classes (10 premolars each) relative to whether the restored teeth were thermocycled or not.

Standardized class V cavities were prepared with the coronal margins located in enamel and the cervical margins placed in cementum. The prepared cavities were restored with either resin composite or resin modified glass ionomer according to manufacturers’ instructions. The restored teeth were finished and polished. The restoration/tooth margins in the surface sealed groups were conditioned using phosphoric acid etch then sealed by either Heleoseal clear or Optiguard surface sealants which were then light cured. Half of the specimens were thermocycled between 5ºC-55ºC for 600 cycles. After thermocycling, teeth were stored in saline solution at room temperature for 24 hours prior to testing. Leakage pattern was tested using methylene blue dye test where teeth were immersed in 2% methylene blue dye solution for 6 hours at room temperature after their isolation except the restored area. The dye then, was removed, thoroughly rinsed and allowed to dry. After 24 hours, teeth were sectioned longitudinally and examined using stereomicroscope and photomicrographs were taken. Microleakage was assessed using two methods, the first was leakage scores and the second was dye penetration surface area. The measurements for microleakage were collected, tabulated and statistically analyzed.

It was found that the use of surface penetrating sealants improved the interfacial relations between resin-based restorations and tooth tissues. The location of cavity margins played a significant role in optimizing the interfacial relations of resin composite restorations to tooth tissues. Surface penetrating sealants were recommended when resin modified glass ionomer was used to restore root cavities. Post-restorative sealing of restorations was not dependent upon the specificity of surface penetrating sealant. Thermocycling adversely affected the marginal seal of restorations whether surface penetrating sealants were used or not.
INTRODUCTION

Class V carious and non-carious dental lesions (abrasion, erosion and abfraction) can be restored with glass ionomer cement, resin reinforced glass ionomer and, resin composite materials. Microgap formation at the restoration tooth interface, particularly at the apical region, occurs due to loss of marginal integrity caused by several factors, including material characteristics, polymerization shrinkage, cavity margin location, morphological and histological constituents of enamel and dentin, patient’s occlusion components, insertion technique and operator compliance with manufacturer’s instructions (Owens and Johnson, 2006).

Glass ionomer cements are widely used in dentistry because of its beneficial properties: chemical adhesion to enamel and dentine, fluoride release, biocompatibility with tooth structure, simple application, esthetic appearance, acceptable abrasion resistance and capacity to be retained on unsupported enamel or non undercut cavities are some of their favorable properties. The two main reasons that have made glass ionomer cements very popular are their permanent ionic bond to tooth structure, and their capacity to release fluoride (Mazzaoui et al., 2000; Yip et al., 2001; Peumans et al., 2005, Van Dijken and Pallesen, 2008). While, glass ionomer restoration protected the tooth from caries but degradation of the restoration surface occurs, composite resin restoration afforded little protection from caries attack although insignifiant degradation (Knight et al., 2006).

Direct composite restorative materials have become a viable substitute to amalgam in many situations due to their excellent esthetic qualities, satisfactory physical and mechanical properties and high dissolution resistance. Problems still exist with polymerization contraction stress, large differences in the coefficient of thermal expansion of composites compared with tooth structure, and with some technique sensitivity; however, new expanding resins, nanofiller technology, and improved bonding systems have the potential to reduce these problems (Puckett et al., 2007). However, polymerization shrinkage of the resin matrix is still considered highly relevant in unsuccessful resin composite direct restorations. The forces generated by polymerization shrinkage can create contraction forces and may induce stress that could disrupt and break bonding at the cavity walls, promoting marginal gaps and subsequent microleakage (Erhardt et al., 2002 and D’Alpino et al., 2006).

Adhesive systems will remain in danger of not totally preventing gap formation and microleakage as long as polymerization contraction and dimensional changes of resin composite are not substantially reduced (Gueders et al., 2006). When a direct composite restoration is made, polymerization shrinkage occurs and the stress generated could reach up to 10 MPa, leading to marginal breakdown and gap formation (Duquia et al, 2006). In vitro studies using commercial composites found a direct relationship between polymerization stress and microleakage in class V restorations (Calheiros et al., 2007 and Cadenaro et al., 2008). Shrinkage stress development must be considered a multi-factorial phenomenon. The development of new restorative techniques and materials that may help minimize this problem (Braga et al., 2005). The low-shrinkage composite showed lower contraction stress non-shrinking resins would represent the ultimate solution to overcome polymerization contraction and stress-related problems (Cadenaro et al., 2008).

Microleakage which is defined as the passage of bacteria, fluid, molecules or ions between a cavity wall and the restorative materials, may be responsible for percolation. The consequences may be postoperative hypersensitivity due to the interfacial hydrodynamic phenomena, bacteria along the restoration margins leading to recurrent caries, marginal staining pulpal irritation and pulp inflammation (Murray et al., 2002 and Plasse et al., 2004). When class V gingival margins (enamel or dentin) were considered separately, enamel margins exhibiting lower degrees of microleakage. The major marginal microleakage occurs on the gingival walls located in dentin or cementum because they do not offer the same conditions for good adhesion to resin composite as enamel has. In addition, moisture control is a complicating factor for the restorative technique (Araujo...
et al., 2006). Rebonding may minimize microleakage at dentin and cementum margins of composite restorations, when a resin system with sufficiently low viscosity is used as a surface sealant (May et al., 1996; Ramos et al., 2000; Ramos et al., 2002; Owens and Johnson, 2006). The influence of thermocycling and thermal stresses on microleakage and marginal integrity of restorative materials was studied; resin composite and glass ionomer restoration margins were significantly affected only under longer dwell times (Guéders et al., 2006 and Cenci et al., 2008). While Pazinatto et al., 2003, stated that no relation existed between the increase of the numbers of cycles and the increase in microleakage. The influence of thermocycling in terms of joint degradation was proved by others (Plasse et al., 2004). So, thermocycling protocol was used to simulate the oral environment effects that restorative materials and adhesive systems are subjected to because of stresses at the adhesive interface generated by the difference in coefficient of thermal expansion and contraction between materials and tooth structure (Duquia et al., 2006).

In an attempt to minimize the undesirable effects of polymerization shrinkage and gap formation, many adhesive systems have been developed and improved, and placement techniques have been introduced. The use of light-curing units that allow control of light intensity has been recommended. Nevertheless, all materials leak to some degree on dentin and cementum, and the efforts to totally eliminate microleakage at the gingival margins of composite restorations have failed. Attempts to seal contraction gaps at tooth/restoration interface by rebonding or impregnating interfacial microdefects with adhesive resins, dentin bonding agents, lightly filled sealing resins, low viscosity surface penetrating sealants, pit and fissure sealants or products specifically developed for this purpose have been reported (Dickinson et al., 1990; Dickinson and leinfelder, 1993; May et al., 1996; Munro et al., 1996; Ramos et al., 2000; Chuang et al., 2001; Ramos et al., 2002; Erhardt et al., 2002; Doray et al., 2003; Arias et al., 2004; D’Alpino et al., 2006; Owens and Johnson, 2006; Araujo et al., 2006; Asaka et al., 2007; Hevinga et al., 2007; Magni et al., 2008 and Kasunoki et al., 2009). The concept of rebonding to seal marginal gaps consists of applying an unfilled resin bonding agent over the margins of the finished restoration, to compensate for the adverse effect of polymerization shrinkage and to guarantee higher quality and durability of marginal adaptation. Penetration of unfilled resin by capillary action would seal the marginal gap, reducing the microleakage (Erhardt et al., 2002). The surface-penetrating sealants are materials with high flow rate developed for rebonding of polymerized composites. The efficiency of these materials in reducing microleakage depends on their low viscosity and high wettability and depth of penetration into microdefects before polymerization is completed (Ramos et al., 2002).

Therefore, this study was carried out to investigate the effect of surface penetrating sealants on leakage pattern of classV resin composite and glass ionomer restorations with different locations of cervical cavity margin. The influence of the following factors on the marginal sealing of class V esthetic restorations was also investigated: Type of restorative material (resin composite versus resin modified glass ionomer), type of surface penetrating sealant (surface sealant versus low-viscosity resin), location of cervical cavity wall (enamel versus cementum) and Thermocycling.

MATERIALS AND METHODS

Two types of aesthetic restorative materials were utilized in the present study: resin composite and resin modified glass ionomer materials. The resin composite system utilized was formed of microhybrid resin composite (Filtek Z250, shade A2, 3M ESPE Dental Products, Germany which is a visible – light activated, radiopaque, restorative composite), Scotchbond Etchant and Adper Single Bond 2 adhesive which is an adhesive used to bond the restoration to the tooth structure. The resin modified glass ionomer (Photac Fil quick aplicap, 3M, ESPE, Germany) used is dual curing glass ionomer cement in capsules composed of powder -containing sodium-calcium-aluminium-lanthanum-fluorosilicate glass and amine activators- , liquid -containing monomers,
oligomers, acrylic and maleic acids, camphor-quinone, stabilizers and water- and Ketac conditioner: which is a dentin conditioner used for dentin pretreatment and removal of the smear layer after tooth preparation. Two types of surface penetrating sealants were used in the study: The first one was low-viscosity, light curing transparent pit and fissure sealant (Heleoseal Clear, Ivoclar Vivadent AG) which consists of Bis-GMA and tri-ethylene glycol dimethacrylate. Additional contents are stabilizers and catalysts. After filling conditioning of the restoration/ tooth surfaces was carried out using (Email Preparator blue, Ivoclar Vivadent AG) which is phosphoric acid 37 wt.% in water, polyvinyl alcohol, and pigments. The second sealant used was unfilled surface sealer (OptiGuard Surface Sealant, kerr MFG, Orange, CA, USA) which is composed of uncured Methacrylate, Esther Monomers and photoinitiators. After filling, conditioning of the restoration/ tooth surfaces was carried out using Scotchbond Etchant. The materials used are listed in Table (1).

A total of 120 sound human upper premolars of nearly even mesiodistal dimensions were used, a digital caliper was used to measure teeth dimensions. Teeth were, then, visually examined using a magnifying lens 4X and by transillumination to ensure that they were free of cracks or hypoplastic defects. Calculus and/or soft tissue deposits were removed from the selected teeth using a hand scaler (Ash instruments, Dentsply, UK). Standardized class V cavities (2x3x1.5mm) in occlusogingival, mesiodistal and depth respectively were prepared in the gingival one third of either the facial or lingual surfaces.

**TABLE (1) The materials used in the study**

<table>
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<tr>
<th>Material</th>
<th>Composition</th>
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<th>Batch number</th>
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<td>Resin composite:</td>
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<tr>
<td>1-Filtek Z250 (A2)</td>
<td>The filler is zirconia/silica, the inorganic filler loading is 60% by volume without silane treatment and particle size 0.01-3.5 µm. The resin matrix contains Bis-GMA, UDMA, Bis-EMA, and TEGDMA resins.</td>
<td>3M ESPE Dental Products, Germany</td>
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<td>2-Scotchbond etchant</td>
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<tr>
<td>3-Adper Single Bond 2 Adhesive</td>
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<td>51202</td>
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<td>Resin modified glass ionomer:</td>
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</tr>
<tr>
<td>1-Photac Fil quick apicapr</td>
<td>Powder: sodium-calcium-aluminium lanthanum-fluorosilicate glass and amine activators. Liquid: monomers, oligomers, acrylic and maleic acids, camphor-quinone, stabilizers and water.</td>
<td>3M ESPE, Germany</td>
<td>297158</td>
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<tr>
<td>2-Ketac conditioner</td>
<td>Polyacrylic acid.</td>
<td></td>
<td>299169</td>
</tr>
<tr>
<td>Heleoseal Clear Pit / Fissure Sealant</td>
<td>Mono/Dimethacrylates, Titanium Dioxide, Dibenzoyl Peroxide Bis-GMA and triethylene glycol dimethacrylate (&gt;99 wt %) additional contents are stabilizers and catalysts (&lt;1 wt %).</td>
<td>Ivoclar Vivadent NA Amhears, NY, USA</td>
<td>J26189</td>
</tr>
<tr>
<td>Email Preparator blue</td>
<td>Phosphoric acid 37 wt.% in water, poly vinyl alcohol and pigments</td>
<td></td>
<td>J22873</td>
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<tr>
<td>Optiguard Surface Sealant</td>
<td>Uncured Methacrylate, Esther Monomers and photoinitiators</td>
<td>Kerr MFG, Orange, CA, USA</td>
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</table>
The coronal margin of the cavity was prepared in enamel, meanwhile, the cervical margin was placed in cementum. The cavity outline was previously marked with a marker to determine an occlusogingival measurement and a mesiodistal width of 2mm and 3mm respectively. The preparation was carried out under air-water spray using a high speed hand piece with carbide inverted cone bur (Komet Burs, H 2314012, Germany) and fissure burs (Komet Burs, H 21314010, Germany). The cavity depth was confirmed using a periodontal probe. The cavity walls, floor and line angles were finished to be smooth and all cavity margins were finished in a butt joint with no cavosurface bevel. The carbide burs were discarded after five teeth preparation.

The prepared teeth were divided into two equal groups (60 premolars each) relative to restorative material used; either resin composite or resin modified glass ionomer. Each group was further subdivided into three subgroups (20 premolars each) relative to type of surface penetrating sealant used. In the first subgroup, cavities were restored without surface sealant application. In the other two subgroups, cavities were sealed with surface penetrating sealants either Heleoseal or OptiGuard respectively after restoration. Each subgroup was further subdivided into two classes (10 premolars each) relative to whether the restored teeth were thermocycled or not.

For teeth restoration using resin composite restoration, cavity walls and floor (enamel and dentin) were conditioned for 15 seconds with Scotchbond Etchant. Then, the cavity was thoroughly rinsed with an air/water syringe for 15 seconds and gently air-dried so that not to desiccate the tooth structure. Adper Single Bond 2 adhesive was applied to the enamel and dentin walls with applicator tip for 15 seconds, using a light brushing motion then, gently air-thinned for 3 seconds, and finally light cured using light curing unit (Cromalux-E, Germany) for 20 seconds. Filtek Z250 resin composite was packed against the cavity walls in one increment, well adapted with Teflon coated plastic instrument and light polymerized for 40 seconds. The light tip was placed as closely as possible to the resin composite surface during polymerization. For teeth restoration using resin modified glass ionomer restoration, cavity walls and floor (enamel and dentin) were conditioned with Ketac conditioner using disposable brush for 10 seconds then rinsed with copious amounts of water. Then, the cavity was dried in 2-3 short intervals with water and oil-free air spray. Aplicap activator (3M ESPE, Germany) was used for mixing the ingredients of the capsule after breakage of the intervening diaphragm. A high speed mechanical amalgamator (Lina-tac, Italy) was used to mix the material for 8-15 seconds. Aplicap applier (3M, ESPE, Germany) was used to apply the restoration to the prepared and conditioned cavity then the restoration was light cured for 20 seconds. All restorations were finished and polished by fine grit aluminum oxide disc (Sof-Lex) under water spray coolant. Each restoration was visually examined to ensure smoothness and absence of restorative materials overhangs on cavity margins (Erhardt, et al., 2002).

Before Heleoseal surface sealant application, tooth/restoration margins were first conditioned with (Email preparator blue) phosphoric acid gel for 15 seconds followed by gentle rinsing and drying. One thin film of Heleoseal was applied to the tooth/ restoration margins, gently air-thinned and light cured for 40 seconds. Before Optiguard surface sealant application, tooth/restoration margins were first conditioned with (Scotchbond etchant) 35% phosphoric acid gel for 15 seconds followed by gentle rinsing and drying. Then, Optiguard surface sealant was applied to the tooth/restoration margins and gently air-thinned and light cured for 40 seconds. Teeth in the thermocycled groups were thermocycled between 5°C and 55°C in separate water baths for 30 seconds in each bath and a transfer time of 30 seconds for 600 cycles (Faculty of Dentistry, Tanta University, Egypt). After thermocycling, teeth were stored in saline solution at room temperature. Before Methylene blue dye application, the apical foramena and the entire tooth surfaces were sealed using two thin coats of nail varnish (Owens & Johnson 2006) then, wrapped with aluminum foil, leaving 1mm distance all around the restoration margin. Teeth were immersed in a 2% methylene blue dye solution for 6 hours at room temperature. The dye then, was removed,
thoroughly rinsed and allowed to dry. After 24 hours, teeth were sectioned longitudinally bucco-palatally by low speed diamond disc into two halves.

Assessment of microleakage was carried out using two methods: leakage scoring method and surface area of dye penetration method. In the leakage scoring method, the longitudinally sectioned teeth were examined using a stereomicroscope (Carl Zeiss, Germany) and the obtained photomicrographs were taken using digital camera (Olympus Camedia C-5060, Japan) using a fixed magnification 25X (Calheiros, et al., 2007). The vertical extent of dye penetration was measured for each specimen. Two readings were recorded at the coronal and gingival margins of the restored cavity and the leakage scores were assessed according to the following parameters: score 0 (No evidence of dye penetration), score 1 (Evidence of dye penetration at the tooth/restoration interface less than half the distance to the axial wall), score 2 (Dye penetration along the tooth/restoration interface greater than half the distance to the axial wall but not reaching the axial wall) and score 3 (Dye penetration extending to the axial wall or beyond). (Erhardt, et al., 2002). In the surface area of dye penetration method, image analysis was done using software (Image J for Windows” version 1.37). The surface area of dye penetration was measured in µm² for each specimen either in the coronal (enamel) or the cervical (cementum) margin. The mean surface area for dye penetration was calculated, tabulated and statistically analysed.

RESULTS

The results of this study are presented in tables (2 and 3) and figures (1-5). Statistical analysis was carried out using SAS program,(SAS, 1988).

A- Dye penetration scores

The percentage of leakage scores for both resin composite and resin modified glass ionomer restorations at the enamel margin for non-thermocycled specimens was 100% for score 1. Upon application of Heleoseal, both groups showed 100% for score zero. After Optiguard surface penetrating sealant application, resin composite restored teeth showed 80% for score zero and 20% for score 1, while resin modified glass ionomer showed 20% for score zero and 80% for score 1. No statistical significant difference existed between resin composite and resin modified glass ionomer in control and Heleoseal surface sealed groups, while there was a statistical significant difference existed in optiguard surface treated group.

After thermocycling, the percentage of leakage scores for resin composite restorations at the enamel margin was 50% for score 1 and 50% for score 2 while it was 60% for score 2 and 40% for score 3 in resin modified glass ionomer restorations. After Heleoseal application, the percentage was 100% for score zero in resin composite restorations and 80% for score zero, 20% for score 1 in resin modified glass ionomer restorations. Meanwhile, after Optiguard surface penetrating sealant application, it was 80% for score 1 and 20% for score 2 in resin composite restored groups and 100% for score 1 in resin modified glass ionomer restored groups. A statistical significant difference existed between resin composite and resin modified glass ionomer restorations at enamel margin of control group after thermocycling. However, no statistical significant difference existed between the two restorations in both of surface sealed groups. Figures (1 and 2) show photomicrographs for non-thermocycled and thermocycled resin composite and resin modified glass ionomer restorations with different dye penetration scores measured. Table (2) and figure (3) show the statistical analysis for the results.

The percentage of leakage scores for resin composite restorations at the cementum margin of non-thermocycled specimens were 20% for score 1 and 80% for score 2. For resin modified glass ionomer, it was 80% for score 1 and 20% for score 2. After application of Heleoseal, resin composite restorations showed 40% for score 1 and 60% for score 1, while resin modified glass ionomer restorations showed 100% for score zero. After Optiguard surface penetrating sealant application, it was found that the resin composite restoration recorded 80% for score 1.
and 20% for score 2 while resin modified glass ionomer recorded 60% for score zero and 40% for score 1. Statistical significant differences existed between resin composite and resin modified glass ionomer restorations at cementum margin of non-thermocycled specimens whether in control or in the two surface sealed groups.

The percentage of leakage scores at cementum margin of the thermocycled specimens were 100% for score 3 in resin composite restoration and were 60% for score 1 and 40% for score 2 in resin modified glass ionomer restorations. After Heleoseal application, resin composite recorded 20% for score 1 and 40% for score 2 and 40% for score 3 while resin modified glass ionomer restorations recorded 20% for score zero and 80% for score 1. For Optiguard surface sealed groups, resin composite restorations showed 100% for score 3 while resin modified glass ionomer restorations showed 60% for score 1 and 40% for score 3. A statistical significant difference existed between resin composite and resin modified glass ionomer restorations in all groups, table (2) and figure (4).

B- Dye penetration surface area

Dye penetration surface area at the enamel margin of non-thermocycled group was 202.2 ± 28µm² for resin composite restoration and 246.6 ± 26.78µm² for resin modified glass ionomer. After Heleoseal application, it was zero for both materials. After Optiguard application, it was 47.5 ± 95µm² for resin composite restoration and 199.8± 117.99 µm² for glass ionomer. A statistical significant difference existed between restorative materials in control group. While, no significant difference was revealed in Heleoseal and Optiguard surface sealed groups.

Thermocycled groups showed dye penetration area 637± 218.04µm² for resin composite and 261.4 ± 68.82 µm² for resin modified glass ionomer. After Heleoseal application, it was 340 ±75.58 µµm² for resin composite and 166.33±103.08 µm² for resin modified glass ionomer. After Optiguard it was 632 ± 240.734 µm² for resin composite and 333± 94.18 µm² for resin modified glass ionomer. A statistical significant difference existed between resin composite and resin modified glass ionomer in all groups, table (3) and figure (5).

In resin composite restorations, dye penetration area showed higher values in cementum than in enamel in the different treated groups either thermocycled or not. In resin modified glass ionomer restorations, non thermocycled groups showed nearly no difference between enamel and cementum in control and Heleoseal groups. Difference was revealed in Optiguard group. With thermocycling, difference was found in the control group and Optiguard groups and there was no difference in Heleoseal group. With thermocycling of resin composite in enamel margin, there was an increase in dye penetration area in control group while, Optiguard group showed the highest increase. The dye penetration surface area at cementum margin showed an increase in all groups. In resin modified glass ionomer restorations in enamel, an increase in area was present in control group and no difference existed in the two surface sealed groups. At the cementum margin, no difference was present in control group and an increase was present in the two surface sealed groups.
Fig. (1) Photomicrographs for resin composite restorations (25X):
(a) non-thermocycled with score 1 coronally and 2 gingivally (control group).
(b) non-thermocycled treated with Heleoseal with score zero coronally and 1 gingivally.
(c) non-thermocycled treated with Optiguard with score zero coronally and 1 gingivally.
(d) thermocycled with score 1 coronally and 3 gingivally (control group).
(e) thermocycled treated with Heleoseal with score zero coronally and 3 gingivally.
(f) thermocycled treated with Optiguard with score 1 coronally and 1 gingivally.

Fig. (2) Photomicrographs for resin modified glass ionomer restorations (25X):
(a) non-thermocycled with score 1 coronally and 1 gingivally (control group).
(b) non-thermocycled treated with Heleoseal with score zero coronally and zero gingivally.
(c) non-thermocycled treated with Optiguard with score 1 coronally and zero gingivally.
(d) thermocycled with score 2 coronally and 1 gingivally (control group).
(e) thermocycled treated with Heleoseal with score zero coronally and 1 gingivally.
(f) thermocycled treated with Optiguard with score 1 coronally and 1 gingivally.
### TABLE (2) Effect of restorative materials and sealing techniques on percentage of dye penetration scores

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<th>Composite No.</th>
<th>Composite %</th>
<th>Glass Ionomer No.</th>
<th>Glass Ionomer %</th>
<th>P</th>
<th>Composite No.</th>
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- \( P \) = Probability level for the effect of material.
- * = Significant at \( p \leq 0.05 \).
- ** = Significant at \( p \leq 0.01 \).
- *** = Significant at \( p \leq 0.001 \).
- NS = Insignificant (\( p > 0.05 \)).
Fig. (3) Effect of restorative materials and sealing techniques on percentage of dye penetration scores in enamel.

Fig. (4) Effect of restorative materials and sealing techniques on percentage of dye penetration scores in cementum.

### TABLE (3) Effect of restorative materials and sealing techniques on dye penetration surface area ($\mu$m²)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Thermo cycling</th>
<th>Material</th>
<th>Composite</th>
<th>Glass Ionomer</th>
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S.D. = Standard deviation.  
NS = Insignificant ($p > 0.05$).  
* = Significant at $p \leq 0.05$.  
** = Significant at $p \leq 0.01$.  
*** = Significant at $p \leq 0.001$.  
P = Probability level for the effect of material.
DISCUSSION

Adhesive systems will remain in danger of not totally preventing gap formation and microleakage as long as polymerization contraction and dimensional changes of resin composite are not reduced (Gueders et al., 2006 and Duquia et al., 2006). In vitro studies found a direct relationship between polymerization stress and microleakage in class V resin composite restorations (Calheiros et al., 2007). Attempts to seal contraction gaps by rebonding with a lightly filled sealing resin have been reported. Surface-penetrating sealants are material with higher flow rate developed for rebonding of polymerized composites (Ramos et al., 2002). Ideally, these materials should have low viscosity and high wettability to provide gap penetration through capillary action, polymerize and provide protection against recurrent caries.

In the present study two aesthetic restorative materials were used for class V restorations, the first was micro-hybrid resin composite (Filtek Z250, 3M ESPE). The second was resin modified glass ionomer which sets via a dominant acid-base reaction and auxiliary photopolymerization. With the addition of resin monomer (2-hydroxyethylmethacrylate [HEMA]) about 4.5 wt% and light polymerized initiators, resin modified glass ionomer is polymerized immediately after visible light irradiation (Chuang et al., 2001). Resin modified glass ionomer is one of the appropriate materials restoring cervical lesions when cavity margins are located on root surface. This is in agreement with Magni et al., 2008 who stated that class V restoration could be performed with resin composite or glass ionomer, though the latter allows simplification of the procedure.

Two materials used as a surface sealant, one was a low-viscosity resin pit and fissure sealant (Heleoseal clear). Its effectiveness in decreasing microleakage was compared to surface sealant specifically marketed for restoration glazing and/or marginal sealing (Optiguard surface sealant). Different materials were selected to evaluate how their composition and physical characteristics influenced the fluidity and penetrability, thus preventing microleakage. This is in agreement with Ramos et al., 2002 who stated that surface-penetrating sealants developed for rebonding of polymerized composites leading to sealing of the defective surface, open margin and provide protection against recurrent caries.

The cavity design selected for the study was class V with coronal margin located in enamel and cervical margin located in cementum. In some studies, the incisal or occlusal margin of enamel was bevelled to increase the enamel surface for adhesion and to improve the esthetic. However, several follow-ups failed to show difference in retention loss between beveled and non-beveled cavities (Van Dijken and Pallesen, 2008). So, it was presumed that cavities prepared to form 90º cavosurface angle is a measure to standardize the variables of the study. Cavities were restored by materials as one increment because cavity depth was 1.5 mm. Teeth were- prepared to receive the sealants- clean, etched and dry in agreement with (Owens and Johnson, 2006) who stated that for satisfactory surface wetting, the surface tension of the sealing material should be equal to or less than the critical surface energy of the restoration/tooth structure. A highly polished, clean, dry surface free of saliva and/or smear layer debris permits favorable wetting for a successful seal. The etched enamel/restoration surface demonstrates an ideal environment for placement of surface sealants, while at
the dentin margin, a satisfactory result is challenging due to the complex nature of dentin.

A thermocycling protocol was used to simulate the oral environment that restorative materials are subjected to, because of stresses at the adhesive interface generated by the difference in coefficients of thermal expansion and contraction between materials and dental structures. This is in accordance to Duquia et al, 2006. The bath temperature, number of cycles and dwell times were chosen based on a review about microleakage studies (Pazinatto et al, 2003; Guéders et al., 2006; Asaka et al., 2007 and Cenci et al., 2008). Most authors used 250 to 1000 cycles with bath temperatures of 5ºC and 55ºC and different dwell times. Currently, no outstanding method is available to determine microleakage. Despite the limitations, such as subjectivity of reading and diffusability of dye due to their molecular weight, dye leakage methodology remains a popular tool to investigate the sealing ability of restorative materials, due to low cost and the technique simplicity (Duquia et al, 2006). Measurements of marginal sealing effectiveness is valuable for predicting clinical performance of restorative materials.

I - Effect of restorative material on dye penetration:

Data of the present study showed that the non-thermocycled control groups revealed no statistical difference in percentage of dye penetration score existed between resin composite and resin modified glass ionomer when the cavity margins are located in enamel. Meanwhile, after thermocycling resin modified glass ionomer restoration showed significantly higher dye penetration scores than resin composite restoration. This may be due to effect of thermocycling leading to deterioration and defective bonding in resin modified glass ionomer.

On the other hand, there was a significant difference in dye penetration surface area between resin composite and glass ionomer restorations in enamel for both thermocycled and non thermocycled control group where resin modified glass ionomer revealed higher leakage than resin composite. In the contrary, no difference was revealed in Heleoseal surface sealed group whether thermocycled or not when dye penetration were assessed by either score or surface area method. Meanwhile, the non-thermocycled Optiguard surface sealed group showed higher leakage for resin modified glass ionomer than resin composite restorations at enamel margin. This may be due to compatibility between two types of resins forming both surface penetrating sealant and resin composite restorations which was absent in resin modified glass ionomer restorations. After thermocycling, no significant difference between the two restorations was observed with Optiguard surface sealant this may be due to deteriorating effect of thermocycling. However, no significant difference in values of dye penetration surface area was revealed between the two restorations after Optiguard application.

Resin composite restorations showed a statistical high value of dye penetration scores in cementum margin (higher leakage) than resin modified glass ionomer in the control and surface treated groups whether thermocycled or not. These results are in agreement with Peumans et al, 2005 and Puckett et al., 2007 who revealed that glass ionomer most effectively and durably bond to tooth tissue. In assessment of leakage using dye penetration surface area method in non-thermocycled specimens the results showed that no statistical difference existed between resin composite and resin modified glass ionomer in control group. While, there were higher of dye penetration area in resin composite than resin modified glass ionomer in surface sealed groups. After thermocycling, higher leakage was observed for resin composite than resin modified glass ionomer in all groups including the control group specimens. These results are in agreement with Yip et al., 2001 who found that SEM fractographic analysis showed that glass ionomer failure were interfacial and mixed failures. There was dehydration cracks, high porosity, and voids with an egg shell-like crust and they concluded that glass ionomer bonding to dentin is not weak. Erhardt et al, 2002, attributed the difference in the area of interfacial gap to incomplete wetting of the surface caused by air bubbles, humidity and/ or debris. They concluded that
thermal cycling may result in loss of fluid resin layer of the sealant. These results are similar to findings previously reported by Silva et al., 2005 and Cenci et al., 2008 who attributed the better performance of glass ionomer to the high dimensional stability of the material, lower thermal conductibility and chemical adhesion to dentin. Van Dijken and Pallesen, in 2008, in their study for dentin bonding efficiency determination, concluded that all systems showed a continuous degradation of the bond with a wide variation with the best retention was for the resin-modified glass ionomer cement.

II- Effect of surface sealants on dye penetration

A better interfacial relation (lower leakage scores) existed at enamel margin resin composite restorations of the non-thermocycled groups after Heleoseal application. Meanwhile, no difference existed between Heleoseal and Optiguard surfaces sealed groups, however, control group showed higher dye penetration scores. For thermocycled specimens, no leakage was recorded at enamel margin when Heleoseal pit/fissure sealant was used and no difference was revealed between control and Optiguard groups that exhibited higher leakage scores. This might be due to aggressive thermal stresses that resulted in debonding which was less manifested with Heleoseal was used due to crosslinking effect of the multiplicity of resin forming this sealant that might decrease the volumetric coefficient of thermal expansion and contraction of the material and enable it to resist gap formation created by these stresses. This is in agreement with D’Alpino et al., 2006 who reported that Heleoseal group revealed the lowest leakage value at enamel margin.

The mean dye penetration surface area of resin composite restoration in non-thermocycled group at enamel margin was higher in control group than both surface sealed groups with no leakage recorded in Heleoseal group. In the thermocycled group no leakage recorded in Heleoseal while no significant difference was revealed between control group and Optiguard that exhibited higher leakage scores. These finding are in agreement with Owens and Johnson, 2006, they found that a significant difference was exhibited at the coronal margins, with Heleoseal pit/fissure sealant and DuraFinish surface sealant exhibiting significantly less leakage than the control group. They also revealed that none of the materials tested were completely resistant to dye penetration. Therefore, varying degrees of marginal leakage existed. They polymerized the resin sealants for only 20 seconds which might result in a lower degree of conversion that might lead to the gap observed in their study.

On the other hand, the percentage of dye penetration scores and surface area for resin composite restorations at cementum margin for non-thermocycled groups showed the least values for Heleoseal followed by Optiguard then control group. While after thermocycling, no difference was obvious between control and Optiguard surface sealed groups when microleakage was assessed by either dye penetration score or surface area technique. This is in agreement with Ramos et al., 2000, who found that in cervical margin in cementum, Optiguard showed similar results to the control group (without sealing). These results are supported by Munro et al., 1996 and Ramos et al., 2002, who concluded that the rebonding technique may minimize microleakage at dentin and cementum margins of composite restorations, when a low viscosity surface sealant was used. In agreement with the results, Owens and Johnson, 2006, found that, at the dentin margin, covering agents showed marginal protection (not necessarily always significant). These results are also in agreement with Magni et al., 2008, who concluded that coating procedure is advisable to restore marginal integrity and reduce gingival microleakage in class V restorations.

In resin modified glass ionomer restorations, the percentage of dye penetration scores and the mean dye penetration surface area for non-thermocycled specimens at enamel margins showed no difference between Optiguard and control group. However, both of them showed higher leakage than Heleoseal that exhibited no leakage. While after thermocycling, the interfacial relation of the control group showed a pronounced degredation represented by a higher leakage scores if compared by
the two other groups. However, upon the use of fissure sealant (Heleoseal), restorations still showed a better interfacial relation if compared to the specific surface sealant (Optiguard). This is in agreement with D’Alpino et al., 2006, concluded that commercial surface sealers evaluated were not able to totally seal controlled-size cavosurface gaps and dentin-bonding agent used to seal the gap performed better.

At cementum margins, the non-thermocycled resin modified glass ionomer restorations Heleoseal surface sealed groups showed no leakage. However those sealed with Optiguard manifested a higher leakage scores and mean surface area value followed by the highest surface area value for control group. This might be due to the surface protecting effect of either specific or non specific sealants which enable the setting reaction and chemical bond of active carboxylic group between glass ionomer and dental tissues. However, the cross linking of Heleoseal ameliorates this effect leading to an optimum seal. The percentage of dye penetration scores and the mean dye penetration surface area value for thermocycled restorations at cementum margins revealed that restorations sealing with non-specific sealant (Heleoseal) showed the least leakage followed by control group then Optiguard surface sealant. The results are in agreement with Dickinson and Leinfelder, 1993, who concluded that low viscosity surface penetrating sealant was effective in enhancing the marginal integrity. The finding of May et al., in 1996, was that application of the resin sealant reduced leakage at the interface between glass ionomer and dentin or cementum. These findings are also in agreement with Chuang et al., 2001, who suggested that resin adhesive can be used as a surface protection to reduce margin microleakage of resin-modified glass ionomer restorations. Cefaly et al., 2001, studying effectiveness of surface protection of resin modified glass ionomer concluded that it was effective. The results also agreed with Arias et al., 2004, who evaluated hydrophilic dentin adhesives to reduce class II restoration microleakage and they concluded that they were effective. The results disagreed with Erhardt et al., 2002 and Asaka et al., 2007, who stated that rebonding with a low-viscosity resin did not reduce marginal leakage of the restorative systems evaluated.

III-Effect of tooth tissue on dye penetration

Both percentage of dye penetration scores and dye penetration surface area methods revealed that resin composite restorations manifested less leakage at enamel margin than cementum whether thermocycled or not for the control and the two surface sealed groups. Generally, the results of this study indicate that microleakage was affected by location of cavity margin (in enamel or cementum). Where, dye penetration in resin composite restored teeth was higher at cementum than enamel. This was in agreement with previous reports by Silva et al, 2005 and Cenci et al, 2008 who attributed these findings to the difference in mineral composition between the two substrates. Enamel is highly mineralized tissue, cementum is less mineralized, thus, presenting more organic compounds. In addition, cementum is more porous, enhancing the permeability to dye in relation to enamel. These results are in agreement with Araujo et al., 2006, who stated that when margins (enamel or dentin) were considered separately, statistically significant differences were observed, with enamel margins exhibiting lower degree of microleakage so, the location of gingival margin influenced the microleakage.

These findings were also in agreement with Owens and Johnson, 2006, who found that enamel had a better sealing ability than dentin whether surface penetrating sealants were used or not. These findings also support the conclusion that enamel surface provides better surface for adhesion of resin-based restorative materials. Enamel surface morphology, primarily inorganic content and water, is very conducive to micro-mechanical adhesion of resin components. The dentin surface substructure and fluid movement, C-Factor (total dentin surface bonding area), together with orientation of the enamel rods and
dentinal tubules to class V walls, play significant roles in tooth surface bonding and long-term restoration success.

The non-Thermocycled resin modified glass ionomer restorations manifested a leakage scores with no difference between enamel and cementum for control and surface sealed groups. Meanwhile, dye penetration surface area method showed that only Optiguard revealed higher leakage at enamel margin than cementum. This might be due to lack of porosity within enamel if compared to cementum which allowed more penetration of the low viscous optiguard sealant to fill up the gaps at restoration cementum interface. After thermocycling, the control group exhibited more leakage at enamel than cementum for both percentage of dye penetration scores and dye penetration surface area methods. However, sealing with Optiguard showed higher leakage at cementum when assessed by both leakage testing methods. In Heleoseal group, cementum showed higher leakage scores than enamel. This might be due to the determinital effect of acid etching prior to sealant application which more manifested after thermocycling especially at cementum.

IV- Effect of thermocycling on leakage and dye penetration

The percentage of dye penetration scores for thermocycled resin composite restorations at enamel margin in control group showed higher leakage relative to non-thermocycled specimens. In assessment of leakage by dye penetration surface area method no statistical difference was recorded between thermocycled and non-thermocycled specimens. This might be due to accuracy of calculations of surface area in image analysis irrespective to the extent of dye penetration in leakage score method. Resin composite restorations sealed with non-specific sealant (Heleoseal) showed no difference between thermocycled and non-thermocycled specimens in both methods of testing. Restorations sealed with Optiguard, thermocycled group recorded higher leakage scores and mean surface area values than non-thermocycled one. This is basically due to the bond deteriorating effect of thermal stresses. At the cementum margin, a statistical difference was revealed between thermocycled and non-thermocycled specimen in all groups where thermocycled specimens recorded higher leakage scores. The highest leakage was for Optiguard and the least was for Heleoseal.

The leakage scores for resin modified glass ionomer restorations at the enamel margin showed a statistical difference between thermocycled and non-thermocycled specimen in control group where thermocycled group exhibited more leakage. Meanwhile, no difference was obvious between them in Heleoseal and Optiguard surface sealed groups. The leakage scores at the cementum margins revealed no statistical difference in control group. While, both of the surfaces sealed groups showed differences between thermocycled and non-thermocycled specimens, where, thermocycled specimens showed higher leakage. These findings are in agreement with Gale and Darvell,1999, who attributed the results to thermal stresses that can be pathogenic in two ways: first, mechanical stresses induced by differential thermal changes that directly induce crack propagation through the bonded interfaces. Second, gap dimensions and gap volume changes pump pathogenic oral fluids in and out of the gap. These findings are also in agreement with Cenci et al.,2008, who found that thermal cycling increased leakage affected resin composite and glass ionomer restorations was significant with a 60-s dwell time. De Munck et al., 2005, in their studied for the durability of adhesion to tooth tissue, they concluded that after about 3 months, all adhesives exhibited mechanical and morphological degradation that resembles in vivo aging effects. These results disagreed with Pazinatto et al.,2003, who studied the effect of number of cycles on microleakage of class V resin composite restorations prepared in bovine teeth (thermocycled 500, 1,000, 2,500 and 5,000 between 5ºC- 55ºC and 15 seconds dwell time). They concluded that there was no relation between the increase of the numbers of cycles and the increase in microleakage.
CONCLUSIONS

Under the conditions of the present study the following conclusions could be drawn:

1. The use of surface penetrating sealants improves the interfacial relations between resin-based restorations and tooth tissues.
2. The location of cavity margins play a significant role in optimizing the interfacial relations of resin composite restorations to tooth tissues.
3. Surface penetrating sealants are recommended when resin modified glass ionomer is used to restore root cavities.
4. Post-restorative sealing of restorations is not dependent upon the specificity of surface penetrating sealant.
5. Thermocycling adversely affected the marginal seal of restorations whether surface penetrating sealants are used or not.

REFERENCES


