Marginal leakage of amalgam and modern composite materials related to restorative techniques in class II cavity (Comparative study)

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ABSTRACT

Background: Restoration of the gingival margin of Class II cavities with composite resin continues to be problematic, especially where no enamel exists for bonding to the gingival margin. The aim of study is to evaluate the marginal leakage at enamel and cementum margin of class II MOD cavities using amalgam restoration and modern composite restorations Filtek™ P90, Filtek™ Z250 XT (Nano Hybrid Universal Restorative) and SDR bulk fill with different restoratives techniques.

Materials and method: Eighty sound maxillary first premolar teeth were collected and divided into two main groups, enamel group and cementum group (40 teeth) for each group. The enamel group was prepared with standardized Class II MOD cavity with gingival margin (1 mm above C.E.J) on both box sides. While the cementum group with the gingival margin (1 mm below C.E.J) on both sides. The enamel and cementum groups were then subdivided into eight subgroups for each (five teeth) with 10 boxes for each group. Subgroups within the main group named according to materials and techniques that were used with it as following: Amalgam subgroup (Permite, SDI), SDR subgroup (DENTSPLY) with bulk technique, Filtek™ P90 subgroup (3M ESPE) with three incremental techniques (Oblique, Horizontal and Centripetal technique), and Filtek™ Z250XT subgroup (3M ESPE) with three incremental techniques (Oblique, Horizontal and Centripetal technique).After specimens were stored in distilled water at 37°C for 7 days. All specimens were subjected to thermocycling at (5° to 55 °C). Microleakage was evaluated by stereomicroscope (20 X). Data were analyzed statistically by Kruskal-Wallis test and Mann-Whitney U-test.

Result: All experimental groups showed leakage at cementum more than enamel groups. SDR bulk fill subgroup showed the highest marginal leakage among all experimental groups followed by Filtek™ Z250 XT subgroup with horizontal technique at both enamel and cementum groups. Silorane and Filtek™ Z250 XT subgroups with oblique technique showed the least marginal leakage followed by centripetal technique at both enamel and cementum groups. Amalgam restoration subgroup shows lesser leakage than SDR bulk fills subgroup significantly at both enamel and cementum groups. While it show higher leakage than Silorane subgroup with oblique technique significantly at enamel margin only.

Conclusion: The limiting factors for marginal leakage are technique and material dependent.

Key words: Marginal leakage, Composite resin, Restorative techniques. (J Bagh Coll Dentistry 2013; 25(3):35-42).

INTRODUCTION

Resin based restorative materials are used worldwide due to their good aesthetic characteristics. Furthermore, their coupling with adhesive systems allows for the advantages of adhesive restorations such as minimally invasive treatment. From the early 1970s, resin their manufacturers concerning mechanical and aesthetic behavior have dramatically improved based restorative materials. This has been mainly achieved by continuous attempts to change their particle morphology particularly, the latest developments in nanotechnology. Contemporary composite materials are very different from those of the 1970s. Not only fillers have changed with time, but also matrix components have also been modified [1].

However, for class II cavities, the factors primarily responsible for microleakage problems are related to the initial shrinkage stress of the composite resin, the difference between the

coefficient of thermal expansion of materials with hard dental tissue, the inaccessibility of the cervical area and, in particular, problems of bonding to the cervical substrate [2].

The incremental technique based on polymerizing with resin-based composite layers less than (2 mm) thick can help achieve good marginal quality, prevent distortion of the cavity wall (thus securing adhesion to dentin) and ensure complete polymerization of the resin-based composite [3].

MATERIALS AND METHODS

Eighty sound maxillary first premolar teeth, non-carious, and non-restored were collected. All of them were checked for cracks, decay, fracture, abrasion or structural deformities using magnifying lens and by transilluminating fiber optic from a light cure device [4,5].All the teeth were cleaned carefully for any calculus deposits with air scaler and teeth were polished with pumice [6].

A restoration template (Manikin) was used to simulate the clinical situation during restoration placement. Maxillary second premolar and

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maxillary canine (artificial teeth) were included in a manikin during the filling procedure, with a space between them to place the tested tooth and fixing by condensation silicon [7-9].

Eighty sound maxillary first premolar teeth were divided into two main groups, enamel group and cementum group (40 teeth) for each. Enamel group will receive a standardized Class II MOD cavity with gingival margin (1 mm above C.E.J) on both box sides (to have 80 boxes). While cementum group with gingival margin (1 mm below C.E.J) on both sides (to have 80 boxes).The enamel and cementum groups are then subdivided into eight subgroups (five teeth) with 10 boxes for each. Subgroups within the main group were named according to materials and techniques that were used with it as following: Amalgam subgroup (Permite), SDR subgroup (DENTSPLY), Filtek™ P90 subgroup (3M ESPE) with three incremental techniques (Oblique, Horizontal and Centripetal technique), and Filtek™ Z250XT subgroup (3M ESPE) with three incremental techniques (Oblique, Horizontal and Centripetal technique).

The dimensions of a standardized Class II MOD cavity preparation boxes were (4 mm) in width bucco-lingually, (4 mm) in depth occlusally from the tip of palatal cusp to pulpal floor and (1.5 mm) depth axially [9,10].

The cavity preparation was carried out on a dental surveyor after positioned the tooth in the template and fixed with condensation silicon. Flat-ended fissure Carbide bur (1 mm in diameter) used to carry out all preparations with a high-speed air water-cooled hand-piece, and a new bur was used for every four preparations to maintain cutting efficiency. All cavosurface line angles for all enamel and cementum groups are not beveled [9].

Each preparation's dimensions was measured and verified with a periodontal probe. One operator performed all preparations, while another investigator checked them before restoration to ensure that they conformed to the dimensions [11].

After complete of cavity preparation, a universal metal matrix band/retainer (Ivory No.8) was placed around each prepared tooth and wedges placement then the boxes would be checked under magnification lens with probe to ensure that there is no any gap.

Amalgam subgroup: (admix, Permite, SDI) mixing according to manufacture instruction and insert to cavity by amalgam carrier and condensed with Amalgam condenser using a weight scale to adjust (400 gm) force till over filled of cavity then removed of access amalgam, carved and burnished to improve smoothness, adaptation and sealing of amalgam at the margins.

Bonding procedure: Self-Etch (Adper™ Easy Bond, 3M ESPE) apply for entire cavity for 20 seconds and air dry for 5 seconds then light cure for 10 seconds according to manufacturer's instructions. This adhesive used with SDR Bulk fill and Z250XT subgroups.

Silorane System Adhesive (3M ESPE) was applied according to the manufacturer's instruction, the primer placed to the entire cavity for 15 seconds then dispersed with a stream of air and light-cured the primer for 10 seconds then the bond rubbed and light-cured for 10 seconds according to the manufacturer's instructions.

Bulk Technique (B.T):The preparations were restored using resin composite bulk placement (single increment) and light cured [12].The SDR placed in a bulk increment (4 mm) according to the manufacturer's instructions then curing for 20 seconds only from the occlusal surface.

Oblique Technique (O.T): The first oblique increment not more than (2 mm) was contacted the gingival, axial, and buccal walls. After the first increment was cured, the second oblique increment was inserted to contact the occlusal, axial, and lingual walls [8]. All increments were light cure 40 seconds for Silorane p90 and 20 seconds for Z250XT subgroups.

Horizontal Technique (H.T): cavity filled with horizontal layering technique not more than (2 mm)[13]. All increments were light cure 40 seconds for Silorane P90 and 20 seconds for Z250XT subgroups.

Centripetal Technique (C.T):Composite increment is applied on the cervical margin against the metal matrix transformation of class II cavities into class I cavities, then the cavity completed by horizontally layering with not more than (2mm) for each increment [14]. All increments were light cure 40 seconds for Silorane p90 and 20 seconds for Z250XT subgroups.

After complete of the restorations, the restorations were finished and polished. All specimens were stored in distilled water at 37°C for 7 days then subjected to thermocycling according to the International Organization for Standardization (ISO) TR11405 standard of 500 cycles, at 5° to 55 °C, with a 15 second dwell time [15,16].

After that, apical foramina were sealed with resin modified glass ionomer (RMGI) cement. In order to prevent dye penetration into the dentinal tubules or the lateral canals, the teeth were coated with two layers of nail varnish except for an area approximately 1 mm around the gingival margin of the restorations [16].The teeth were then immersed in 2% Methylene Blue for 24 hours at 37°C. After removal from the dye solution, the teeth rinsed with running water [17].

The root will be embedded in chemically cured acrylic resin with the long axis of tooth by dental surveyor up to (2 mm) apical to the cemento-enamel junction (CEJ) to facilitate handling during sectioning procedures [11].

The specimens were sectioned in mesio–distal direction at the center of the restorations with water coolant to obtain two similar dental fragments. The fragment that exhibited greater dye leakage was evaluated and the other was discarded [18].

Dye penetration evaluated at the gingival margin of the longitudinally sectioned teeth examined using a stereomicroscope (20 X). The extent of dye penetration was scored by two independent observers according to a five-points scale [11]:

0 = no leakage.

1 = leakage extending to the outer half of the gingival seat.

2 = leakage extending to the inner half of the gingival seat.

3 = leakage extending up to 2/3 of the axial wall.

4 = leakage extending through the axial wall up to the pulpal floor.

The data was analyzed using Kruskal-Wallis test to detect the significant differences among the groups. Further analysis with Mann-Whitney U-test was conducted for pair-wise comparisons among groups.

RESULTS

The microleakage percentage in Filtek™ Silorane p90 (O.T) subgroup has lowest value (60% score zero at enamel and 40% score zero at cementum), while in SDR subgroup has highest value (30% score 3 at enamel and 30% score 4 at cementum) as in Bar chart (Figure 1).

The statistical analysis of data by Kruskal-Wallis non-parametric one-way ANOVA test revealed highly significant difference (p < 0.001) among the subgroups in enamel and cementum groups (Table 1) and (Table 2).

The descriptive statistics will be presented as the mean, median, minimum value and maximum value of microleakage of enamel and cementum groups, are summarized in Table 3and 4.

To determine which mean is significantly different from which others, select Box-and-Whisker Plot from the list of Graphical Options and select the mean notch option (Figure 2, 3).

The box represents the inter-quartile range. You have three points: the first middle point (the median), and the middle points of the two halves (what I call the "sub-medians"). These three points divide the entire data set into quarters,

called "quartiles". The top point of each quartile has a name, being a "Q" followed by the number of the quarter. Therefore, the top point of the first quarter of the data points is "Q_1". Note that Q_1 is also the middle number for the first half of the list, Q_2 is also the middle number for the whole list, and Q_3 is the middle number for the second half of the list.

The whiskers represent the highest and lowest microleakage values.

All experimental groups showed leakage at cementum more than enamel groups. SDR bulk fill subgroup showed the highest marginal leakage among all experimental groups followed by Filtek™ Z250 XT subgroup with horizontal technique at both enamel and cementum groups. Silorane and Filtek™ Z250 XT subgroups with oblique technique showed the least marginal leakage followed by centripetal technique at both enamel and cementum groups. Amalgam restoration subgroup shows lesser leakage than SDR bulk fills subgroup significantly at both enamel and cementum groups. While it show higher leakage than Silorane subgroup with oblique technique significantly at enamel margin only.

DISCUSSION

In this study, there is no significant difference within the Filtek™ Silorane subgroup at both (enamel and cementum groups) with oblique, centripetal and horizontal placement technique, although oblique technique shows the least mean leakage value among them. The possible explanation may be that the oblique layering technique given minimal contact with the cavity walls during polymerization. Therefore, there is a lower cavity configuration factor (C-factor) due to the large free surface permitting resin to flow during polymerization [19].These finding come in agreement with the study of Mereuta et al. [20].

Mereuta et al. [20] evaluated the clinical performances of class II composite restorations performed with different restorative techniques for 12 months as longitudinal study in vivo. There is no significant difference in marginal adaptation between the oblique layering technique and the centripetal build-up technique but oblique technique by mean was the best followed by centripetal and horizontal technique respectively.

The result of this study shows that the oblique technique is the best technique to be used with Filtek™Z250 XT subgroup, although there is no significant difference between oblique and centripetal technique but the mean value for oblique technique is less at both enamel and cementum groups. On the other hand, the

horizontal placement technique with Filtek™Z250 XT subgroup shows high mean leakage value with significant difference in comparison to the oblique and centripetal technique with both enamel and cementum groups. This may be attributed to that as we said previously to the high cavity configuration factor (C-factor), in which the C-factor with horizontal technique is 2, while the C-factor for oblique technique is 1.5 with minimum bonded surface permitting the resin to flow during polymerization. These results come in agreement with Eakle and Ito [21], Neiva et al.[22], Duarte and Saad [23].They shows that the oblique layering technique has revealed less microleakage than bulk or other incremental techniques.

Szep et al. [24] postulated that in the proximal box first horizontal increment tended to pull away from the cervical margin during the polymerization shrinkage.

Giachetti et al. [19] concluded that large volume of increment could not compensate the polymerization shrinkage. These finding come in agreement with our study because the increment used to fill by horizontal technique is large by volume in comparison to the increment used for oblique technique.

The result of this study shows that the centripetal technique comes after the oblique technique in reducing the microleakage with both materials P90 and Z250XT subgroups with no significant difference between them.

This may attributed to that in centripetal technique. A thin proximal layer placed towards the matrix band was cured before adjacent composite increments were applied into the cavity. This can reduce the V/A ratio, where V is the cavity volume and A is the area of the cavity walls. This first layer had less contact with the lateral walls. Alternatively; the first layer of the centripetal technique had no contact to the pulpoaxial walls and thus had less tendency to contract toward this wall and away from the cervical floor during polymerization [24]. This explanation comes in agreement with study of Mereuta et al. [20].

Mereuta et al. [20] postulated the centripetal and oblique techniques, which were better than horizontal technique.

By excluding of the placement techniques used in this study, the result revealed that the Filtek™ Silorane subgroup as composite restoration show low value of marginal leakage at both enamel and cementum groups in comparison to Filtek™Z250 XT and SDR subgroups. The possible explanation may be:

A. The difference in the matrix system, the methacrylates based composite are cured by radical intermediates while Filtek™ silorane via cationic intermediates. The ring-opening polymerization mechanism of *oxirane* moieties in the silorane monomer was responsible for the reduced shrinkage (less than 1%). Therefore, the polymerization shrinkage of silorane based composite did not start immediately after light exposure, but an expansion occurred instead [25].

B. Filtek™ silorane took the longest time to reach gel and vitrification points (low degree of conversion).So the Filtek™ silorane based composite react with slow set (slower to polymerize) , that allow for flow of material and stress relaxation[25].

C. Low water sorption and solubility of Filtek™ Silorane, due to presence of hydrophobic Siloxane and quartz filler is more stable to leach into water than those with metallo-silica glasses [26-28].This result comes in agreement with Al-Qahtani et al. [29].

Al-Qahtani et al. [29] show that the Filtek™ Silorane have lowest mean value of water sorption and solubility after storage for one week in distilled water due to hydrophobicity of Silorane followed by Filtek™ Z250 XT and SD respectively.

SDR subgroup shows the highest mean value of microleakage at both enamel and cementum group among all other subgroups with significant difference in comparison to Filtek™ silorane, Filtek™Z250 XT and amalgam subgroups. The possible explanation may be:

1. High water sorption and solubility of SDR, due to:

A. Chemistry of SDR, that contain ethoxylated bisphenol A dimethacrylate (EBPADMA), modified urethane dimethacrylate (MUDM), and triethylene glycol dimethacrylate (TEGDMA) resins, and the last two are more hydrophilic than EBPADMA, so higher water sorption is expected from this material compared with other resin based composite materials [30,31].

B. SDR contains barium glass, strontium glass, some studies have shown that barium and strontium glasses are more readily leached into water than silica particles, and that the resin-based composite with quartz filler is more stable than those with metallo-silica glasses [26,27]. This result comes in agreement with Al Qahtani et al. [29] who showed that the SDR have high mean value of water sorption and solubility after storage for one week in

distilled water in comparison to Filtek™ Silorane and Filtek™ Z250 XT.

2. Even with low stress that is provided by SDR about (1.5 Mpa), but shrinkage volume is still high about (3.5%) followed by Filtek™ Z250 XT about (1.7%) and least shrinkage volume of Filtek™ Silorane (less than 1%) according to manufactures. This agrees with a clinical report of Christensen [32] who concluded that the volumetric shrinkage and stress of bulk fill resins are not less than other conventional restorative resins.

Boaro et al. [33] showed that there is a weak relationship between shrinkage rate and shrinkage stress. Matthias et al. [34] shows that none of the SDR groups caused less gap-free margins compared to incrementally layered resin composites.

In this study, the amalgam restoration subgroup show higher marginal leakage with significant difference in comparison to P 90(O.T) in enamel group only. This may be related to that what we mentioned previously about low shrinkage characteristic of Silorane (less than 1%) and the better performance of oblique placement technique over the other techniques (centripetal and horizontal) [19,20].

Additionally, the coefficient of thermal expansion of amalgam that is about three times greater than that for dentine. This coupled with the grater diffusivity of amalgam, results in considerably more expansion and contraction in the restoration than in the surrounding tooth when thermocycling may cause micro leakage around the filling. In addition, there is no adhesion between amalgam and tooth substance [15].

In this study, the amalgam restoration subgroup show better performance with lower leakage significantly in comparison to SDR bulk fill and Z250 XT (H.T) with both enamel and cementum groups. The possible explanation may be due to that what we mentioned previously about the shortcoming of SDR bulk fill and bad performance of horizontal technique.

In this study, all subgroups show low mean leakage value at enamel than cementum group. The possible explanation may be:
A. The bond strength to enamel is usually higher than bond strength to dentin. However, enamel is a highly mineralized tissue composed of more than 90% (by volume) hydroxyapatite. While, dentin is less favorable bonding substrate due to its heterogenous structure [35].
B. The orientation of dentin 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 [35].

C. The presence of fluid inside the dentinal tubules that diluted the dentin conditioner may decrease its potential for demineralization of the intertubular and peritubular dentin, and eventually affect on hybrid layer thickness [36].

This result in agree with Bogra et al. [9]. Bogra et al. [9] show that the dentin surface on the gingival floor of class II preparations may be a surface on which good hybrid layer formation is difficult.

Mann-Whitney U-test show significant difference at ($P < 0.05$) of SDR subgroup only while there is no significant difference between other materials and techniques subgroups. The possible explanation may be related to that the actually time of 20 second as recommended from manufacture to cure (4 mm) thickness of SDR thought to be insufficient for optimum polymerization, mainly on the bottom surface specially for the Bulk build up technique. The increasing of the distance from bottom up to the cusp tip makes a serious problem in curing causes the resin composite on the bottom surface and disperses the light of the light curing unit. As a result, when the light passes through the bulk of the composite, the light intensity is reduces and the energy of the light emitted from a light-curing unit decreases drastically when transmitted through resin composite, leading to a gradual decrease in degree of conversion of the resin composite material at increasing distance from the irradiated surface [37,38].

Christensen [32] who compared different types of bulk fill resins (SDR), he concluded that the most bulk fill reins have many challenges which still exist for most material that include the light cure does not reach the bottom of deep box form.

Hilton and Ferracane [39] compare the depth of cure of various bulk-placement composites as assessed by hardness. They found the SDR did not reach accepted hardness when used as (4 mm) increment.

According to this study, it can be concluded that:
1. The SDR bulk fill not recommended to be used in deep class II cavity.
2. Low-shrinkage materials such as Silorane and Z250 XT recommended to be used with oblique and centripetal incremental techniques rather than horizontal incremental technique.

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Table 1. Kruskal-Wallis test for enamel group

Test	Statistical value	P -value
Kruskal-Wallis	31.6876	0.000

Table 2.Kruskal-Wallis test for cementum group

Test	Statistical value	P -value
Kruskal-Wallis	41.0285	0.000

Table 3. Descriptive statistics of microleakage for Enamel group

Group	Materials & Techniques subgroups	Sample No	Mean	Median (Q1)	Median (Q2)	Median (Q3)	Minimum value	Maximum value
Enamel	**P 90 (O.T)**	10	0.40	0	0	1	0	1
	Z250 XT (O.T)	10	0.50	0	0	1	0	2
	P 90 (H.T)	10	0.60	0	1	1	0	1
	P 90 (C.T)	10	0.60	0	1	1	0	1
	Z250 XT (C.T)	10	0.90	0	1	2	0	2
	Amalgam	10	1.00	1	1	1	1	1
	Z250 XT (H.T)	10	1.80	1	1.5	3	0	3
	SDR	10	2.10	1.5	2	3	1	3

Table 4. Descriptive statistics of microleakage for Cementum group

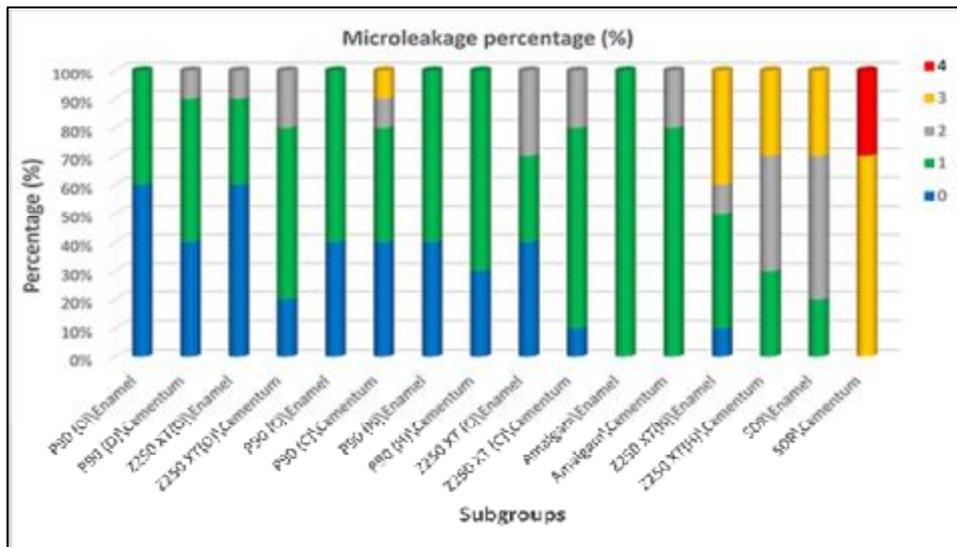| Group	Materials & Techniques subgroups	Sample No	Mean	Median (Q1)	Median (Q2)	Median (Q3)	Minimum value	Maximum value
Cementum	**P 90 (O.T)**	10	0.70	0	1	1	0	2
	P 90 (H.T)	10	0.70	0	1	1	0	1
	P 90 (C.T)	10	0.90	0	1	1.5	0	3
	Z250 XT (O.T)	10	1.00	0	1	1.5	0	2
	Z250 XT (C.T)	10	1.10	1	1	1.5	0	2
	Amalgam	10	1.20	1	1	1.5	1	2
	Z250 XT (H.T)	10	2.00	1	2	3	1	3
	SDR	10	3.30	3	3	4	3	4

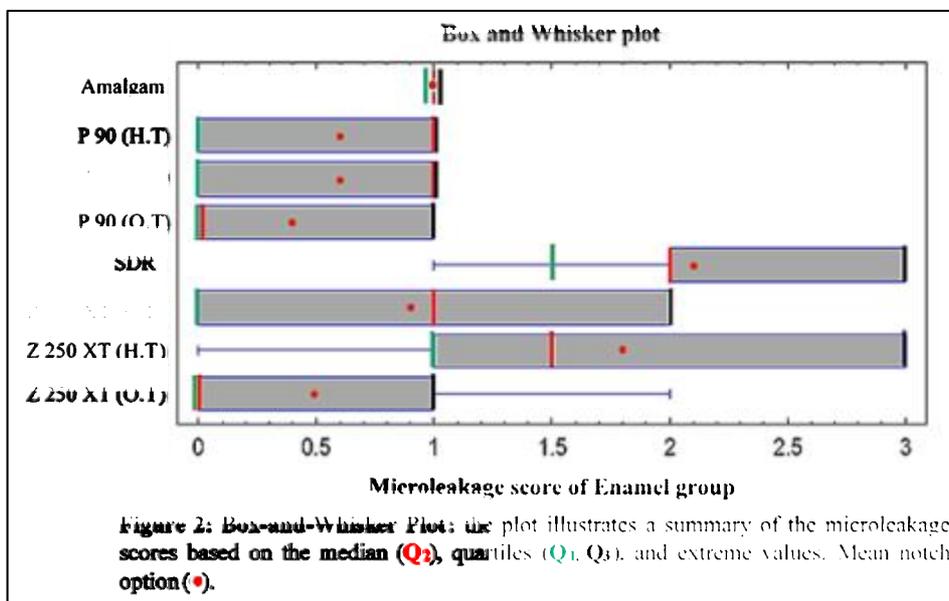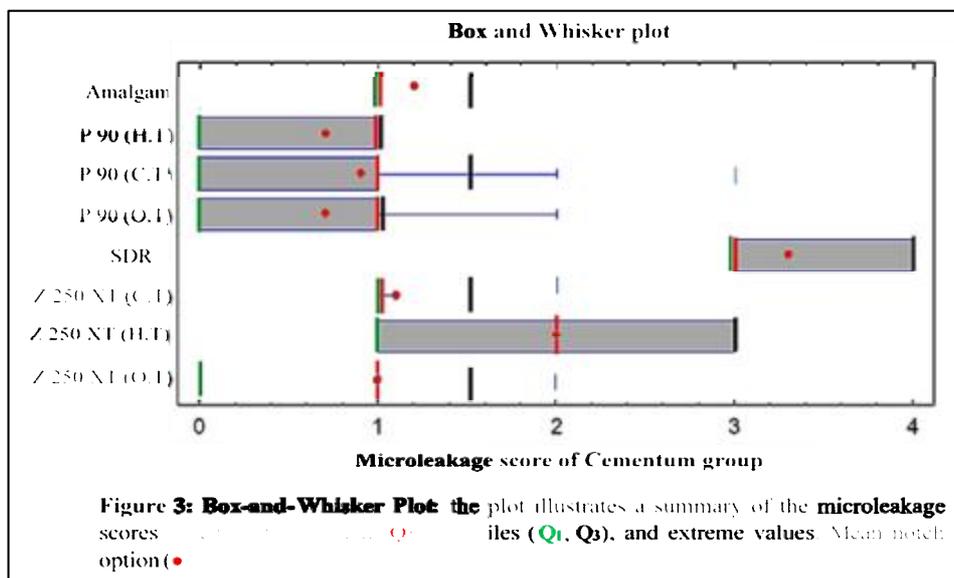**Figure 1. Microleakage percentage of Enamel and Cementum**

Figure 2: Box-and-Whisker Plot: the plot illustrates a summary of the microleakage scores based on the median (Q₂), quartiles (Q₁, Q₃), and extreme values. Mean notch option(●).

Figure 3: Box-and-Whisker Plot: the plot illustrates a summary of the microleakage scores ... (Q₁, Q₃), and extreme values. Mean notch option(●)