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Comparison of microleakage of Scotchbond™ Universal Adhesive with methacrylate resin in Class V restorations by two methods: Swept source optical coherence tomography and dye penetration

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ABSTRACT

Background: One of the most important factors in restoration failure is microleakage at the restoration interface. Furthermore, a new generation of bonding, Scotchbond Universal (multi-mode adhesive), has been introduced to facilitate the bonding steps. The aim of this study was to compare the microleakage of Class V cavities restored using Scotchbond™ Universal with Scotchbond Multi-Purpose in two procedures.

Materials and Methods: Eighteen freshly extracted human molars were used in this study. Thirty-six standardized Class V cavities were prepared on the buccal and lingual surfaces. The teeth were divided into three groups: (1) Group A: Scotchbond Universal with "self-etching" procedure and nanohybrid composite Filtek Z350. (2) Group B: Scotchbond Universal with "total etching" procedure and Filtek Z350. (3) Group C: Scotchbond Multi-Purpose and Filtek Z350. Microleakage at enamel and dentinal margins was evaluated after thermocycling under 5000 cycles by two methods of microleakage assay: swept source optical coherence tomography (OCT) and dye penetration. Wilcoxon's signed-rank test and Kruskal–Wallis test were used to analyze microleakage.

Results: In silver nitrate dye penetration method, group A exhibited the minimum microleakage at dentin margins and group C exhibited the minimum microleakage at enamel margins ($P < 0.05$). Furthermore, in OCT method, group C demonstrated the minimum microleakage at enamel margins ($P = 0.047$), with no difference in the microleakage rate at dentin margins.

Conclusion: Scotchbond Universal with "self-etching" procedure at dentin margin exhibited more acceptable performance compared to the Scotchbond Multi-Purpose with the two methods.

Key Words: Microleakage, optical coherence tomography, universal adhesive

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INTRODUCTION

Cosmetic dental treatments have become more popular in recent years. Demand for beautiful teeth and charming smile is synchronized with new service developments and advances in dental materials (composites and bonding). Composite polymerization process is associated with polymerization shrinkage. Excessive shrinkage is the most important factor in restoration failure. This shrinkage results in stresses between the tooth and composite, creating small gaps

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in the area, which causes leakage of saliva, bacterial penetration and secondary caries.[1] Laboratory studies of microleakage are often performed in Class V restorations. Samples are subjected to thermocycling and mechanical loads to create conditions similar to the oral environment.[1,2] It is estimated that 10,000 thermal cycles is approximately equal to 1-year of thermal fatigue in clinical conditions.[3]

Several techniques have been used to evaluate microleakage in various studies, including dye penetration, electrochemical method, fluid filtration, radioisotope labeling and analysis by electron microscopy.[4]

Among the different methods, dye penetration is the most common because of its sensitivity, convenience and ease of use.[4,5] However, dye penetration method is very subjective and inappropriate because of its destructive nature that requires sectioning of teeth. These disadvantages have led to the development of newer diagnostic technologies on adaptation of restorations, including three-dimensional (3D) technique of micro-computed tomography (micro-CT).[6,7]

Recently, optical coherence tomography (OCT) has been introduced as a noninvasive cross-sectional imaging technique to evaluate internal biological systems at a submicron scale.[8] This method is a promising imaging aspect, in which sectioning and processing of samples are not required and the structure of tissues and biomaterials can be observed.[9] OCT is based on low-coherence interferometry concept. In simple terms, the samples are irradiated with laser beams and the average intensity of the scattered signals of the surface provides information about the depth of scattering and reflection of samples. These signals are converted to an image with the Santec OCT Image Viewer software.[8]

In dentistry, OCT is used for the research and diagnosis of periodontal diseases and caries lesions.[10,11] Swept source OCT (SS-OCT) is the latest spectral scattering tool which provides images with better resolution and higher scanning speed by laser with regulated wavelength as a light source.[12] Some studies have mentioned OCT capacity in observation of gap formation at tooth–restoration interface.[13,14] However, with the current knowledge, a few reports in dental articles have been made to develop methods for qualitative and quantitative measurement of interfacial gaps between the tooth and restoration by OCT and have been validated by conventional microscopic techniques which are destructive for the interface.

SS-OCT (OCT-2000®, Santec, Komaki, Japan) used in this study is similar to what has been described by Shimada.[15] SS-OCT system has a frequency range which includes the external cavities by the frequency of high-speed laser whose probe power is <20 MV in safe ranges defined by the American National Standard Institute. The light beam of the focused source is reflected on the sample and scanned in two dimensions (x, z) using a handheld probe over the margin. Then, the scattered light is returned from the sample to the system, becomes digitized in the time scale, and is analyzed in the Fourier domain until the light reflection profile is revealed in the penetration depth at any point. Two-dimensional (2D) cross-sectional images can be created by converting B-scan raw data to gray-scale image.[15,16] Based on the results of Bakhsh studies, a 250-μm distance is considered the minimum distance between the sections of 2D images for gap analysis.[17] The important mechanism for detecting different structures in OCT images is their combination.[18] According to the optical phenomenon, when the light of two environments with different components and very different refractive indices (e.g., air and composite) spreads, a part of the light is reflected. This phenomenon justifies the light of the image created by the OCT signal in the presence of the gap (air), even in the absence of a contrast medium.

In the microscopic method with dye penetration, the samples are immersed in a solution revealer such as silver nitrate, fuchsin or methylene blue. Color penetrates through the resin–dentin interface in any area of the formed gap. However, this method only shows the penetration depth through the given plane section of teeth and depends on the quality and situation of the dental section.[4,19]

Some researchers believe that clinical leakage is less than the color penetration in a laboratory situation. By default, a lower penetration depth of dye is more related to the higher clinical survival rate, especially for marginal discoloration and less secondary caries.[20] The review of microleakage, using dye penetration test, has shown that the results are independent of the restorative material and all the materials exhibit some degree of leakage.[20] Typical dentin margins show more dye penetration compared with the enamel margins.[21]

With advances in dental materials in the field of composites and a desire to simplify the process of business, various materials have been introduced to dentistry, and the use of multicomponent classic bonding has largely decreased.[20]

Recently, a single-component adhesive has been introduced, named “multi-mode” or “universal.” Depending on the indication, the adhesive is used in a “self-etching” procedure to achieve the shortest possible treatment time. The aim of “selective enamel etching” is to maximize the adhesion to the tooth enamel and minimize postoperative sensitivities. In “total etching” procedure, a prior phosphoric acid etching step cannot be restricted to the tooth enamel. Scotchbond Universal or Single Bond Universal is one of the “all-in-one” adhesives, which has been introduced recently. The presence of 10-methacryloyloxydecyl dihydrogen phosphate (MDP) molecule in the composition of this adhesive likely leads to higher microtensile bond strength.[22]

This study was undertaken to compare the microleakage of one-step multi-mode adhesive with the fourth-generation classic bonding. Two methods were employed: evaluation of microleakage with silver nitrate dye and marginal adaptation with SS-OCT.

The hypotheses of this study were as follows: (1) Application of universal bonding to enamel and dentin margin by two procedures of “self-etching” and “total etching” does not influence the microleakage compared with the control group. (2) There is no difference between two methods of “silver nitrate dye” and “SS-OCT” in the microleakage evaluation.

MATERIALS AND METHODS

In this experimental study, 18 molars were ultrasonically cleaned of calculus and soft tissues immediately after extraction, disinfected in a 0.5% T-chloramine solution, and then kept in distilled water until the test time. Class V cavities were prepared on the buccal and lingual aspects of all the teeth, with 3-mm mesiodistal dimension, 2-mm occlusogingival and 1.5-mm depth of cavity using a high-speed handpiece and a diamond 0.8 fissure bur (Iran, Tizkavan) along with the flow of water at the same time. After the preparation, the gingival edge was placed 1 mm below the cementoenamel junction and the occlusal margin of the cavities was placed on the enamel. After preparation of five cavities, the bur was changed. The cavity sizes were measured in each level with a periodontal probe.

The samples were randomly assigned to one of the three groups (each group consisting of six teeth and 12 restorations).

Group A: According to the instructions, Single Bond Universal (3M ESPE St Paul, MN, USA) was applied, as a self-etch procedure, with a microbrush to all the cavities, without etching, especially on enamel edges. They were applied for 20 s, thinned by mild air pressure for 5 s, and then cured for 10 s at 850 mW/cm² using an LED-D (Guilin Woodpecker Medical Instrument, China) light-curing unit. Next, the cavity was restored with Filtek™ Z350 XT compositeb (3M ESPE, ST Paul, USA) with two oblique increments (gingivo-occlusal) and cured for 20 s.

Group B: In a total-etch procedure, all the cavities were etched by 35% Scotchbond Etchant (3M ESPE, ST Paul, USA) for 15 s and then washed for 10 s. After the cavity was gently dried through an air syringe while leaving a slightly moist surface, the cavity was dipped by a microbrush saturated with Single Bond Universal (3 MESPE, ST Paul, USA) for 20 s and after applying 5 s of air flow, it was light-cured for 10 s. Finally, the cavity was restored with Filtek™ Z350 XT composite (3M ESPE, ST Paul, USA) with two oblique increments (gingivo-occlusal) and light-cured for 20 s.

Group C: According to the manufacturer’s instructions, Scotchbond™ Etchant was applied on the enamel and dentin for 15 s and then rinsed for 15 s, and excess water was removed through an air syringe while leaving a moist surface. In the next step, Adper™ Scotchbond™ Multi-Purpose Primer (3M ESPE, ST Paul, USA) was applied to the enamel and dentin and dried gently for 5 s. Then, Scotchbond™ Multi-Purpose adhesive (3M ESPE, ST Paul, USA) was applied to enamel and dentin and light-cured for 10 s using LED-D at 850 mW/cm². Finally, the cavity was restored with Filtek™ Z350 XT composite (3MESPE, ST Paul, USA) with two oblique increments (gingivo-occlusal) and light-cured for 20 s. All the specifications of the materials are summarized in Table 1.

All the samples were polished with a composite polishing diamond bur and polishing disks, OptiDisc (Kerr, USA). While being in distilled water, they were kept in an incubator at 37°C for 24 h. Then, the samples were placed in “DORS Teb” device for

Table 1: Materials used in this study

Material	Composition	Manufacture
Filtek Z350 A high-performance, versatile nanocomposite	Bis-GMA, UDMA, Bis-EMA, TEGDMA, zirconium/silica nonagglomerated particles	3M ESPE St Paul, MN, USA
Single Bond Universal Adhesive (one bottle for all cases total etch and self-etch)	MDP phosphate monomer (optimizes self-etch performance, provides chemical bonding) HEMA Vitrebond™ copolymer (provides more consistent bonding to dentine under moist or dry conditions) Filler Ethanol Water Initiators Silane	3M ESPE St Paul, MN, USA
AdperScotchbond™ Multi-Purpose[a] (total etch adhesive)	Scotchbond™ etchant (35% phosphoric acid) Adper™ Scotchbond™ Multi-Purpose Primer (HEMA, Vitrebond™ Copolymer) Scotchbond™ Multi-Purpose adhesive (HEMA and BIS-GMA)	3M ESPE St Paul, MN, USA

[a]The gold standard for strength, reliability and versatility. Bis-GMA: Bisphenol A-glycidyl methacrylate; UDMA: Urethane dimethacrylate; Bis-EMA: Bisphenol A polyethylene diether dimethacrylate; TEGDMA: Triethyleneglycol dimethacrylate; HEMA: 2-hydroxyethyl methacrylate; MDP: Methacryloyloxydecyl dihydrogen phosphate

thermocycling, under 5000 cycles at 5°C and 55°C for 30 s exposure time and 15 s dwell time.

After the thermocycling procedure, the samples were placed under the SS-OCT machine (Santec, Japan) and 3D scans were taken from the prepared cavities. In this study, six sections of the restored cavities were prepared in different regions. Because of limited access to image analysis software, leaking margins were scored similar to the silver nitrate microscopic method. From these 3D scans, six 2D images were processed and analyzed [Figure 1]. To reduce the difference in air refraction index of the restored samples before laser irradiation, distilled water was used on the samples so that it covered the entire surface.

To observe the leaking margins by microscopy and dye penetration, the root end of the teeth was sealed and all the teeth surfaces, up to 1 mm from the edge, were completely sealed by two layers of nail varnish (Bourjois, France) and immersed in 1 mol of silver nitrate solution (17 g of silver nitrate in 100 mL of distilled water) in a dark environment for 6 h. Then, the samples were washed with distilled water, dried and placed in a developing solution (Iran Chemical World Co, Iran) under a fluorescent light for 12 h. Next, the specimens were mounted in polyester and sectioned using a cutting machine (Presi, Mecatome, T201 A, France) and a bilateral diamond disk with 0.3 mm longitudinal thickness with 2000 rpm rotational speed.

During the cutting, water flow was used for cooling as well as washing the debris. The cut samples were observed under a stereomicroscope LEICA EZ4D (Tokyo, Japan) under magnifications of ×10 and ×40. Images were taken of them [Figures 2 and 3] and evaluated for leakage at two locations on occlusal and gingival margins.

Silver nitrate penetration was ranked in four levels: [Figure 4]

- Zero: No dye penetration
- One: Dye penetration to 1/2 or <1/2 of the wall
- Two: Dye penetration over 1/2 of the wall
- Three: Dye penetration to the axial wall, without involving the axial wall
- Four: Dye penetration to the axial wall, involving the axial wall.

To evaluate the amount of microleakage between the groups, Kruskal–Wallis test was used, and for two-by-two comparisons of the groups, Dunn test was used. Furthermore, to compare the microleakage between the occlusal and gingival margins, Wilcoxon's signed-rank test was used in each group. Data were analyzed with SPSS for Windows, Version 16.0. (Chicago, SPSS Inc.).

RESULTS

According to the Wilcoxon's signed-rank test in silver nitrate dye method, the lowest leakage at occlusal margin was as follows: group C (fourth-generation bonding), group B (universal total etch bonding), and group A (universal self-etch bonding) ($P < 0.05$).

At gingival margin, the lowest leakage included group A (universal self-etch bonding), group C

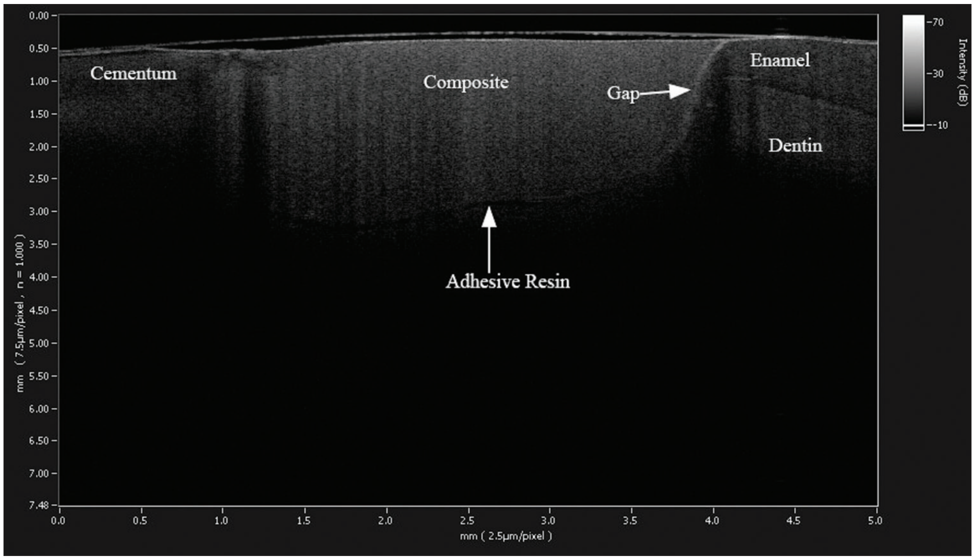

Figure 1: Cross-sectional image from the swept source optical coherence tomography three-dimensional scan. Short arrow shows an interfacial gap.

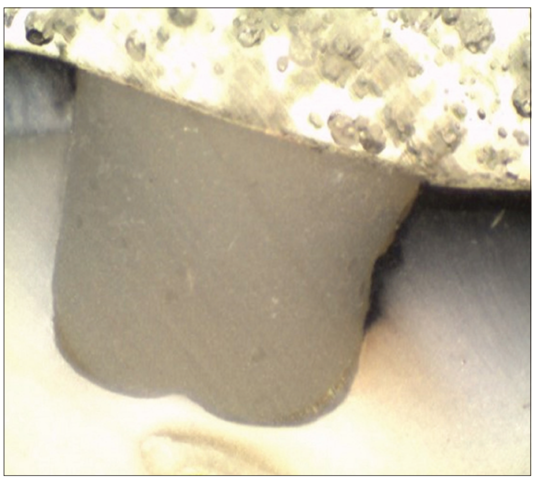

Figure 2: Microleakage observed under a stereomicroscope (LEICA EZ4D, Tokyo, Japan) at magnification of ×40. Leakage sample with Rank 1 is at the occlusal margin and Rank No. 2 is at the gingival leakage in group B.

(fourth-generation bonding), and group B (universal total etch bonding) ($P < 0.05$).

In the OCT method, the lowest leakage on occlusal margin was found in group C, group A, and group B (fourth-generation bonding <universal self-etch bonding <universal total etch bonding), respectively.

At the gingival margin, the leakage values were the same as silver nitrate.

In the silver nitrate dye method, the position of cavity margins was evaluated for each bonding system by *post hoc* one-way ANOVA. It was shown that the leakage at enamel and dentin margins exhibited a significant difference from each other in all the groups, except group B (universal total-etch bonding). In group C, leakage at the dentin margin was more than that at the enamel margin, and in group A (universal self-etch), leakage at the enamel margin was more than that at the dentin margin ($P < 0.05$) [Table 2].

In the OCT method, only group A (universal self-etch) showed a significant difference ($P < 0.05$). In group A, similar to silver nitrate dye method, leakage at the enamel margin was more than that at the dentin margin, and no significant difference was observed between the enamel and dentin margins in other groups.

In comparison of the two methods of silver nitrate dye and SS-OCT, the highest correlation in the gingival margin was in score 0 (20.5%) and in score 1 (15.1%), respectively. Hence, these two methods yielded similar results in relation to the amount of microleakage at gingival margins (38.4%). At the enamel margin, the highest correlation was in score 0 (26.6%) and in score 1 (22.8%). Hence, these two methods yielded the same results in relation to the amount of microleakage at enamel margins (54.5%).

DISCUSSION

With recent advances, composites have desired physical and esthetic properties, but their polymerization shrinkage and related stress is one of the most important complications. Microleakage at tooth–dental restoration interface is the main factor affecting longevity, in which restorative margins could be colored or it might lead to secondary caries, increased sensitivity in the restored tooth, and also pulp pathological injury.[23]

On the other hand, because of a tendency to simplify the process, new one-step bonding systems have been introduced to the dental market. Bond strength of the composite to dentin is more challenging than bonding to enamel.[24] However, to evaluate the optimal use of materials in this study, Class V restorations were used with the occlusal margin in enamel and the gingival margin in dentin.

Marginal quality is a critical key to assess the clinical prognosis of restorations. The most acceptable leakage evaluation procedure is dye penetration test.[5] However, due to the destructive nature of this method, other novel methods without tooth preparation and probable clinical applications have been adopted.

Table 2: Microleakage evaluation in cavity margins

Group	Ag enamel - Ag dentin	Enamel OCT - dentin OCT
Group A (significant)	0.000	0.006
Group B (significant)	0.197	0.202
Group C (significant)	0.007	0.096

OCT: Optical coherence tomography; Ag: ($AgNO_3$) Silver nitrate dye penetration

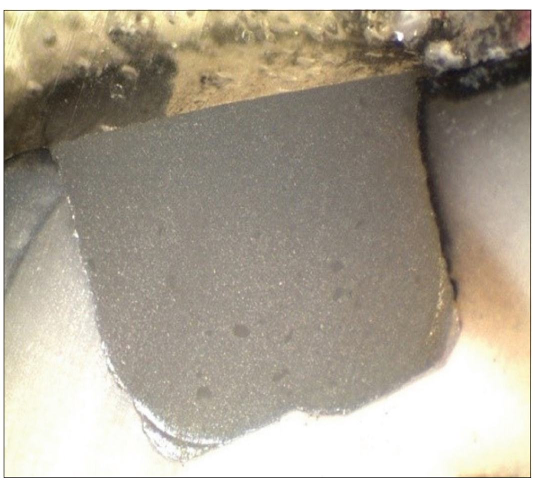

Figure 3: Microleakage observed under a stereomicroscope (LEICA EZ4D, Tokyo, Japan) at magnification of ×40. Leakage sample with rank 3 is at the gingival margin and rank 0 is at the occlusal in group C.

Post hoc one-way ANOVA showed that group A at dentin margin had less leakage compared with group B (universal total-etch) and group C (Scotchbond fourth generation), which was statistically significant.

There was a statistically significant difference between groups A (universal self-etch) and C (fourth-generation Scotchbond) at both enamel and dentin margins of the restorations, with group A exhibiting more microleakage at the enamel margin, whereas group C showed more microleakage at the dentin margin.

Lower leakage level at the dentin margin in group A in comparison with group C was similar to the results reported by Van Landuyt *et al*.[25] and Ermis *et al*.[26] As demonstrated previously, the dentin exposed by the total-etch bonding is very susceptible to hydrolytic and enzymatic destructive processes, while self-etch bonding partially etches the dentin and leaves some amounts of hydroxyapatite around the collagen grid. Thus, functional monomers (10-MDP) in bonding, with a combination affinity for hydroxyapatite, create ionic bonds, resulting in bond stability.[27,28]

De Munck *et al*. showed less durability of Scotchbond Multi-Purpose in contact with the copolymer polyalkenoic acid with a high molecular weight.[29] However, Ozgünaltay and Onen[30] reported a retention rate of 95% after 3 years, and in a study by Platt *et al*.,[31] a retention rate of 81% was reported after 3 years. Furthermore, a series of *in vitro* studies on the long-term effectiveness of Scotchbond Multi-Purpose have reported some challenges.[29,32,33] It was shown that the phase separation through copolymer filtering by the collagen grid and sediment occurred as a clear gel on the exposed collagen grid.[34,35] This factor prevents sufficient intermediate penetration, with the hybrid layer being more susceptible to destruction.

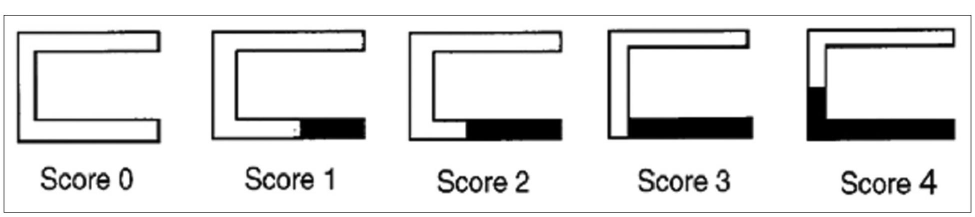

Figure 4: Microleakage ranking.

In addition, Muñoz *et al*.[36] found using universal bonding with the self-etch approach that nanoleakage level was similar to Clearfil SE Bond, which is the gold standard of self-etch adhesives.

Significant differences were observed only at dentinal margins between groups A (universal self-etch) and B (universal total-etch), with group B exhibiting much more leakage. No significant difference was recognized at the enamel margin. This implies that in the universal bonding, etch-and-rinse approach leads to no leakage reduction. This finding is consistent with the results reported by Marchesi *et al*.[37] They reported the lowest level of silver nitrate dye leakage with the application of Scotchbond Universal with self-etch approach, compared with etch-and-rinse approach and Prime and Bond NT. The difference between the bond strength and nanoleakage in self-etch and etch-and-rinse approaches can be explained by the fact that the bonding of MDP benefits from the residual apatite on the collagen fibers, creating chemical bonds with bond stability and longevity.[38-40] Yoshida *et al*. demonstrated that the created bond by the 10-MDP is effective and also more stable in aqueous media, compared with 4-MET and Phenyl-P.[41]

Thus, the lower leakage at gingival margin with the use of Universal bonding with self-etch approach can be justified in comparison with the two other groups. Further leakage values at dentin margins in etch-and-rinse approach are justified because phosphoric acid causes deeper decalcification (up to 6.3 mm) as compared to self-etch approach. Muñoz *et al*.[36] concentrated on instant characteristics of universal adhesives to dentin, including bond strength, nanoleakage and conversion degree of Clearfil SE Bond, Adper Single Bond, Peak Universal Adhesive, Scotchbond Universal, and All-Bond Universal. They suggested that Scotchbond Universal showed the lowest microleakage between the seventh-generation universal adhesives. However, using the total etch approach, the nanoleakage level was less than Single Bond and in the self-etch approach, the nanoleakage level was reported similar to Clearfil SE Bond.[36]

There were statistically significant differences between groups B (universal total etch) and C (fourth-generation Scotchbond) at both enamel and dentin margins of restorations, with group B exhibiting more leakage. The difference in the enamel margin is primarily due to differences in the acidity of two bonding agents. Scotchbond Universal is a one-step self-etch adhesive with pH ≈ 3 while pH of Scotchbond Multi-Purpose is <1; therefore, the latter adhesive etches the enamel better and results in better bonding in the enamel. In addition, the Scotchbond Universal does not have a hydrophobic layer to create a strong bond. At the dentin margin, more leakage of universal total-etch is associated with the calcium pick-up and reduced sites of bond binding to calcium by MDP and polyalkenoic acid.

The most common method to observe leakage between the tooth and restorative material is silver nitrate dye. Sectional cutting and observing the depth of dye penetration in the interface by optical microscopy or scanning electron microscopy are other methods. Clinically, radiographic evaluation and observation methods are usually used for evaluation of marginal adaptation. However, only the translucent region larger than 40 mm is detectable in radiography. Therefore, wrong conceptions in restoration replacement can occur.[42] Disadvantages of dye penetration leakage tests led to the development of newer diagnostic technologies for research on restoration adaptation, like 3D-CT (micro-CT).[6,7]

In this study, gap values were diagnosed from cross-sectional (2D) images. Providing 3D images from 2D scans is also possible, but it was not utilized in the study because of software limitations and lower resolution of images. According to the results of Sadr and Bakhsh, a 250-mm distance was considered the minimum distance between the sections of 2D images for gap analysis.[17] In the OCT method, the number of sections are more than the silver nitrate dye (two sections) and the results might show more adaptation.

For OCT in the present work, fourth-generation bonding exhibited the lowest microleakage [bright areas at the interface in Figure 1] at the occlusal margin after thermocycling. *Post hoc* one-way ANOVA revealed statistically significant differences between group A (universal self-etch) and group C (fourth-generation Scotchbond) at enamel margins of restorations. Thus, group A exhibited more microleakage at the enamel margin. This finding was similar to silver nitrate dye method. Scotchbond Universal is a one-step self-etch adhesive and contains MDP and polyalkenoic copolymer acid. Research works suggest that the copolymer competes with MDP by binding to calcium hydroxyapatite.[43] In addition, by destruction of MDP bond to dentin, polyalkenoic copolymer acid with high molecular weight prevents monomer concentration during polymerization.[38] Given all these factors, more leakage of Scotchbond universal at the occlusal margin can be justified relative to the gold standard fourth-generation bonding. Etching enamel with phosphoric acid before using the self-etch primer is effective in improving the adhesive marginal integrity of the enamel.[44] Unlike silver nitrate dye method, at dentinal margins, no significant difference was observed which is probably due to the different method of leakage identification. Thus, despite the destructive nature of silver nitrate dye method, significantly higher microleakage values have been reported due to the very small size of silver particles.

There was no statistically significant difference between groups A (universal self-etch) and B (universal total-etch) at both enamel and dentin margins. However, the seventh-generation bonding with both total-etch and self-etch approaches in OCT evaluation showed the highest amount of bright areas at the interface of enamel margins.

Statistically significant differences were found between groups B (universal total-etch) and C (fourth-generation Scotchbond) only at enamel margins, with group B exhibiting more leakage. The reason was likely because of the presence of a hydrophobic layer in fourth-generation Scotchbond. Muñoz *et al*.[36] evaluated the impact of the hydrophobic resin layer on the effectiveness of universal adhesive bonding in terms of the bond strength and leakage. They observed that the use of Heliobond hydrophobic resin layer led to a higher bond strength and less nanoleakage in the Scotchbond Universal with a total-etch approach. They also reported that the nanoleakage was more related to adhesive composition (mixture combination) than the bonding strategy.[36]

In addition, groups A (universal self-etch) and B (universal total etch) exhibited the lowest and highest leakage, respectively, at the gingival margin using OCT. However, no significant differences were observed between the three groups ($P > 0.05$). In the current study, Scotchbond Universal was actively used on the dentin according to the manufacturer's instructions. Previous studies have clearly reported that the active use of self-etch adhesives resulted in better performance of bonding.[45,46] Based on our results, the active use of total-etch Scotchbond Universal leads to higher leakage values compared with self-etch Scotchbond Universal, although the difference was not significant. However, further studies are necessary to confirm this hypothesis.

Based on the results, the leakage at enamel and dentin margins with silver nitrate dye method was significantly different in all the groups, except total-etch Scotchbond Universal. However, in the OCT method, only self-etch Scotchbond Universal resulted in a significant difference.

Furthermore, according to the results, the highest correlation at the gingival margin was in score 0 with 20.5% and score 1 with 15.1% for the silver nitrate and OCT method, respectively. Hence, these two methods had the same results with 38.4% at the gingival margin. At the occlusal margin, the highest correlation was detected in score 0 with 26.6% and in score 1 with 22.8%. Hence, these two methods had 54.5% similarity in their results at occlusal margins. In similar studies, OCT method was used to quantify the amount of leakage at the resin–dentin interface and validated by confocal microscopy. In a study by Bakhsh *et al*.,[17] values of increased intensity of SS-OCT signal at the interface were the same and related with interfacial gap diagnosed by confocal laser scanning microscope. In addition, SS-OCT technique was reported as a noninvasive method for gap diagnosis at the depth and bottom of composite restorations.

SS-OCT provides rapid information of the entire cavity, which facilitates chairside diagnosis. However, due to the size limitation, this method cannot be used effectively in different locations, including posterior areas of the oral cavity. The development of intraoral probes makes the real-time observation of dental structures possible and is useful for noninvasive patient treatment planning. Moreover, the SS-OCT provides a practical and promising technique to evaluate dental materials and the marginal integrity of the restoration *in vitro* and *in vivo*.

CONCLUSION

Research on marginal leakage is a part of the material laboratory tests, but longevity and restoration quality have been influenced by many factors, which are entirely under laboratory conditions and have no simulation capabilities. However, based on laboratory research, forecasting the integrity of marginal restorations is possible under various clinical conditions.[47] At the dentin margins, self-etch Scotchbond Universal exhibited the best results in the silver nitrate dye method. At the enamel margin, group C (Scotchbond Multi-Purpose) exhibited the best results by the silver nitrate dye method.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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