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Original Article

Effect of operator variability on microleakage with different adhesive systems

Emel Karaman[1], A. Ruya Yazici[2], Burak Aksoy[3], Erdem Karabulut[4], Gul Ozgunaltay[2], Berrin Dayangac[2]

[1]Department of Restorative Dentistry, Faculty of Dentistry, Ondokuz Mayıs University, Samsun, Turkiye, [2]Department of Restorative Dentistry, Faculty of Dentistry, Hacettepe University, Ankara, Turkiye, [3]Department of Pediatric Dentistry, Faculty of Dentistry, Hacettepe University, Ankara, Turkiye, [4]Department of Biostatistics, Faculty of Medicine, Hacettepe University, Ankara, Turkiye

Correspondence: Dr. A. Ruya Yazici
Email: ruyay@hacettepe.edu.tr

ABSTRACT

Objective: The objective of this study was to evaluate the effect of operator variability on microleakage with different adhesive systems. **Materials and Methods:** A total of 180 standardized Class V cavities were prepared on facial and lingual of 90 extracted human premolar teeth and randomly assigned to five groups according to the adhesive systems used ($n = 36$): Prime and Bond NT (PB), Single Bond (SB), Futura Bond NR, Xeno III (XE) and Adper Prompt-L-Pop (LP). The adhesive groups were then further subdivided into three operator groups according to level of clinical experience ($n = 12$): An undergraduate student, a research assistant and a faculty member. All cavities were restored with same composite resin. The restored teeth were thermocycled (500 cycles, 5-55°C) then immersed in 0.5% basic fuchsin and measured for leakage under a stereomicroscope. Statistical analyses were performed with the Kruskal-Wallis and Mann-Whitney U tests. **Results:** Significant inter-operator variation was found in the enamel margins in the XE group with significantly higher microleakage when used by the undergraduate student ($P < 0.05$). Although no significant differences in microleakage were found between adhesive systems for the research assistant and faculty member ($P > 0.05$), significant differences were observed between PB and LP, PB and XE, SB and LP and SB and XE in the enamel margins for the undergraduate student ($P < 0.05$). **Conclusion:** Microleakage of adhesive systems is more dependent on interactions between the operator and adhesive material than on the choice of adhesive material.

Key words: Dentin bonding, microleakage, operator variability

INTRODUCTION

For the last two decades, composite resin restorations used with adhesive systems have gained popularity as a result of patient demand for tooth-colored restorations, public concerns related to mercury in amalgams and the desire for minimally invasive restorations. Increased concerns about preservation of healthy tooth structures favored the use of resin composite rather than amalgam.[1] Thus, the use of amalgam has decreased dramatically in many countries despite its mechanical properties, low material price, rapid application and excellent long-term results.[2] Composite resins are mercury-free and thermally non-conductive and they match the shade of natural teeth and bond to the tooth structure through the use of adhesive systems.[3,4] On the other hand, polymerization shrinkage remains a major drawback. As a result of polymerization shrinkage, marginal leakage generally occurs at the interface between the restorative material and the tooth, which leads to post-operative sensitivity, recurrent caries and pulpal complications.[5,6] Therefore, the ability to

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produce a uniform, long lasting seal to the tooth structure is a challenge in dentistry.[7] Today, many new adhesives have been introduced in the dental market. Adhesive systems can be classified as either "etch-and-rinse" or "self-etch."[8] Contemporary adhesive systems ("three-step etch-and-rinse adhesive systems") comprise separate conditioning, priming and bonding steps. Most modern adhesive systems combine these functions into two steps; the priming and bonding steps are combined.[9] With the self-etch adhesive systems, no separate etching or rinsing steps are needed. Conditioning and resin monomer infiltration in enamel and dentine occur simultaneously; thus, reducing the potential for degradation over time[8] and eliminating the critical post-etch rinsing and drying steps of total etching adhesive systems.[10] Although the literature on this matter is controversial,[11] the self-etch adhesive systems reduce the technique sensitivity during handling and application.[8]

Successful bonding to hard tissues is a fundamental requirement before placement of resin composites. It is important to note that the success of adhesive restorative treatment relies not only on the improvement of the material properties and handling technique, but also on the skills and knowledge that general practitioners possess in regard to a material's properties, limitations and correct use.[2,12,13]

This study evaluated the effect of operator variability on microleakage of two etch-and-rinse and three self-etch adhesive systems after operators' calibration. The null hypothesis tested was that operator skill and experience would not influence the success of adhesive restorative treatment.

MATERIALS AND METHODS

Samples, cavity preparation and restoration

In this study, 90 extracted human premolar teeth without decay, cracks or previous restorations were used. The teeth were stored for less than 3 months in 0.1% thymol solution and then scaled and cleaned.[2] A total of 180 standardized Class V cavities without bevels (4 mm width, 2 mm height, 2 mm depth) were prepared with a water-cooled high-speed handpiece at the cement-enamel junction on the buccal and lingual surfaces. The teeth were randomly assigned to five groups according to the adhesive systems used ($n = 36$): Two etch-and-rinse adhesives (Prime and Bond NT [PB] and Single Bond [SB]) and three self-etch adhesives (Futura Bond NR [FB], Xeno III [XE], Adper Prompt-L-Pop [LP]). The adhesive groups were then further ascribed to three operators with different levels of clinical experience ($n = 12$): An undergraduate dental student with 1 year of clinical experience, a research assistant with 4 years of clinical experience and a faculty member with 19 years of clinical experience [Figure 1]. Each adhesive was applied by each operator according to the manufacturer's instructions and light cured with the same halogen light-curing unit (Hilux Expert, Benlioğlu Dental, Ankara, Turkey). The curing light was checked with a curing radiometer before the start of the study.

Group I - PB

The prepared cavities were etched with 37.5% phosphoric acid (Scotchbond Etchant, 3M Dental

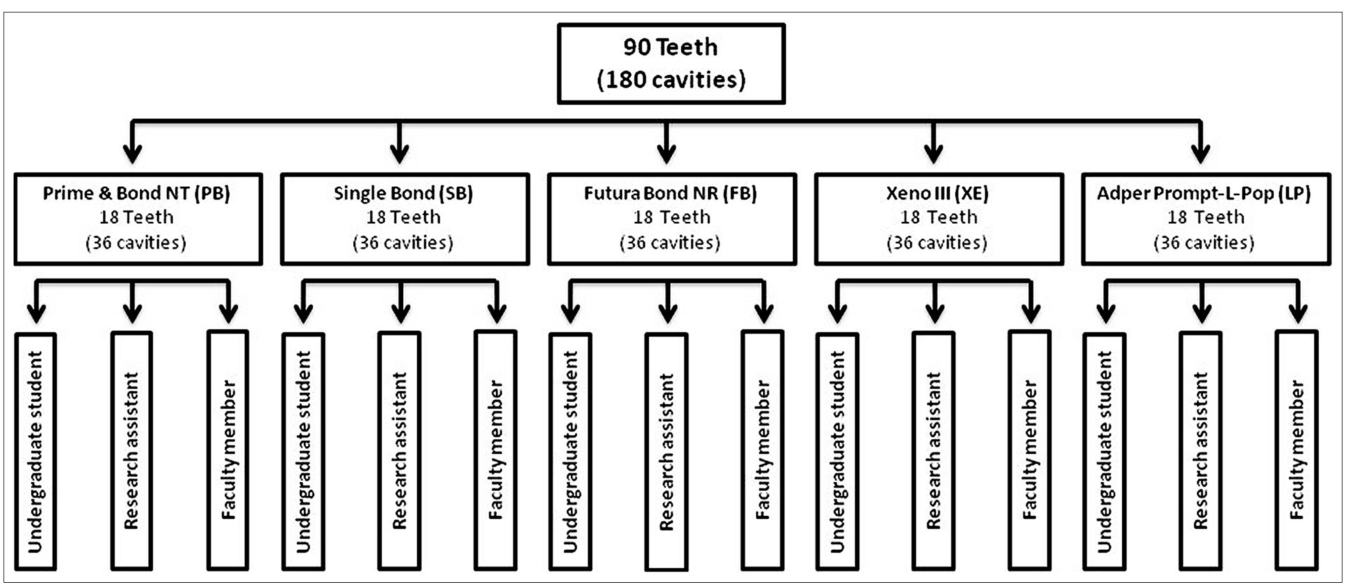

Figure 1: Flowchart of the study

Products, St Paul, MN, USA) for 30 s in enamel and 15 s in dentin, then thoroughly rinsed with water for 30 s and gently dried with compressed air leaving the surface moist and taking care not to desiccate the dentine. A two-step etch-and-rinse adhesive, PB (Dentsply Caulk, Milford, DE, USA), was applied to the cavity and left undisturbed for 20 s. The solvent was removed with air from a dental syringe for 5 s and the adhesive was light cured for 20 s.

Group II - SB

The prepared cavities were etched in the same way as group I with 37.5% Scotchbond phosphoric acid gel, rinsed for 30 s with water, then briefly and gently dried with compressed air leaving the surface moist and taking care not to desiccate the dentine. Two consecutive layers of SB (3M ESPE, St Paul, MN, USA; two-step etch-and-rinse adhesive) were applied to the cavity and left undisturbed for 20 s. The solvent was removed with air from a dental syringe for at least 5 s and the adhesive was light cured for 20 s.

Group III - FB

The mixed self-etch adhesive FB (Voco, Cuxhaven, Germany) was applied to the cavity under scrubbing with moderate finger pressure for 10 s and air dried to a thin film with a gentle stream of air. The adhesive was light cured for 20 s.

Group IV - XE

One drop each of liquid A and B were mixed homogeneously for 5s. The mixed self-etch adhesive XE (Dentsply Caulk, Milford, DE, USA) was then applied to the cavity surface with a disposable applicator, left for at least 20 s and then light cured for 20 s.

Group V - LP

The mixed self-etch adhesive LP (3M ESPE, St Paul, MN, USA) was applied to the cavity under scrubbing with moderate finger pressure for 15 s and air dried to a thin film with a gentle stream of air. The adhesive was light cured for 20 s.

The adhesive systems used in the study are listed in Table 1. After adhesive application, all cavities were filled with one bulk increment of a hybrid composite resin, Spectrum TPH (Dentsply Caulk, Milford, DE, USA) for 40s using Quartz-Tungsten-Halogen curing unit (Benlioglu, Ankara, Turkey) with a power density of 550 mW/cm^2. All specimens were then stored in distilled water at room temperature (37°C) for 24 h.[14] After 24 h, the restorations were finished with the aluminum oxide discs (Sof-Lex, 3M ESPE Dental Products, St. Paul, MN, USA). All the procedures, except for adhesive system application and light curing, were carried out by the same dentist.

Specimen preparation and microleakage investigation

Teeth were thermocycled for 500 cycles between 5°C and 55°C, with a dwell time of 30 s and a transfer time of 5 s, in accordance with the recommendation of the International Organization for Standardization (ISO/TS 11405).[15] The specimens were sealed with a composite resin at the root apices and all external surfaces were isolated with two layers of nail varnish (Flormar, Kosan Cosmetics, Kocaeli, Turkey) except for 1 mm around the restorations. The specimens were stored in distilled water at room temperature for 24 h before they were immersed in 0.5% basic fuchsin for 24 h.[14]

The specimens were rinsed under tap water and dried. Teeth were sectioned ocluso-gingivally with an Isomet 4000 slow-speed saw (Buehler, USA). Two mesial-distal cuts of each tooth were measured for leakage under an Olympus SZ61 stereomicroscope (Olympus Corporation, Japan) at ×40 magnification by two examiners who were blind to the specimen preparation.

Table 1: Materials used in the study

Adhesive system	Lot no.	Manufacturer	Chemical composition
Prime and Bond NT	507002201	Dentsply, Caulk, Milford, DE, USA	Di-and trimethacrylate resins, PENTA, functionalized amorphous silica, stabilizers, photoinitiators, cetyl amine hydrochloride, acetone
Single Bond	20051007	3M ESPE, St Paul, MN, USA	HEMA, Bis-GMA, dimethacrylates, methacrylates pendant polyalkenoic acid copolymer, ethanol, water
Futura Bond NR	521079	Voco, Cuxhaven, Germany	HEMA, Bis-GMA, BHT, ethanol, organic acids, fluorides
Xeno III	303001361	Dentsply Caulk, Milford, DE, USA	Liquid A: HEMA, water, ethanol, silicon dioxide. Liquid B: Phosphoric acid modified methacrylate resin, UDMA, BHT, camphorquinone, ethyl dimethylaminobenzoate
Adper Prompt-L-Pop	7020111528	3M ESPE, St Paul, MN, USA	Methacrylated phosphoric esters, Bis-GMA, camphorquinone, stabilizers, water, 2-HEMA, polyalkenoic acid, stabilizers

Bis-GMA: bis-phenol A diglycidylmethacrylate, HEMA: 2-hydroxyethyl methacrylate, BHT: butylated hydroxytoluene, UDMA: Urethane dimethacrylate, PENTA: Dipentaerythritol pentacrylate monophosphate

At the beginning of the study, in order to test the intra- and inter-examiner reproducibility, weighted Kappa values were calculated. The Kappa values were high (0.95) and showed powerful intra- and inter-examiner agreement.

Microleakage values were measured in ordinal scale and rated on a scale from 0 to 3 at the enamel walls: 0 = No leakage, 1 = Dye penetration within the enamel of the occlusal wall, 2 = Dye penetration reaching the dentine of the occlusal wall up to the axial wall and 3 = Dye penetration spreading along the axial wall. Microleakage at the dentine walls was also rated on a scale from 0 to 3: 0 = No leakage, 1 = Dye penetration up to half way along the gingival wall, 2 = Dye penetration within the gingival wall up to the axial wall without reaching the axial wall and 3 = Dye penetration spreading along the axial wall of the cavity[13,16] [Figure 2].

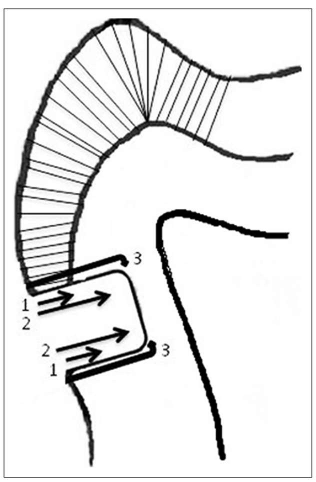

Figure 2: Schematic illustration of dye penetration scores

If disagreement occurred between the evaluators, a consensus was obtained after reexamination of the specimen by both investigators.

Statistical evaluation

To determine the significance of differences between the groups, the data were analyzed with the Kruskal-Wallis non-parametric test. Pairwise comparisons were made using the Mann-Whitney U test. The preset level of significance was 0.05.

RESULTS

In none of the groups dye penetration was completely prevented. Tables 2 and 3 show the microleakage scores for enamel and dentine, respectively.

For the PB, SB and FB groups, there were no significant differences among operators with regard to microleakage in enamel and dentine. This was also true for the faculty member and research assistant with regard to all other adhesive systems ($P > 0.05$). Significant differences were observed between the undergraduate student and other operators in the enamel and dentine in the XE group ($P < 0.05$). In the LP group, microleakage at enamel margins was significantly higher for the undergraduate student ($P < 0.05$), but there was no significant difference between the operators in dentine ($P > 0.05$).

For the faculty member, the lowest microleakage occurred for PB in enamel and PL in dentine. No specimens received scores of 2 and 3 for enamel. For the research assistant, the microleakage scores of adhesive groups in enamel and dentine were

Table 2: The microleakage scores for enamel

Adhesive systems	*N*	Faculty member					Research assistant					Undergraduate student				
		0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean
Prime and Bond NT	12	11	1	0	0	0.08	8	3	1	0	0.41	9	3	0	0	0.41
Single Bond	12	6	6	0	0	0.50	8	4	0	0	0.33	9	3	0	0	0.41
Futura Bond NR	12	5	7	0	0	0.58	8	4	0	0	0.33	5	6	0	1	0.75
Xeno III	12	7	5	0	0	0.41	8	4	0	0	0.33	2	10	0	0	0.83
Adper Prompt-L-Pop	12	7	5	0	0	0.41	9	3	0	0	0.25	4	8	0	0	0.66

Table 3: The microleakage scores for dentine

Adhesive systems	*N*	Faculty member					Research assistant					Undergraduate student				
		0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean
Prime and Bond NT	12	9	3	0	0	0.25	7	3	2	0	0.58	5	7	0	0	0.58
Single Bond	12	7	5	0	0	0.41	9	3	0	0	0.25	8	4	0	0	0.33
Futura Bond NR	12	10	1	0	1	0.33	7	5	0	0	0.41	8	2	0	2	0.66
Xeno III	12	8	3	1	0	0.41	8	4	0	0	0.33	4	6	2	0	0.83
Adper Prompt-L-Pop	12	6	6	0	0	0.5	12	0	0	0	0	10	2	0	0	0.16

statistically similar. Only specimens in the PB group were given a score of 2 for enamel and dentine. The most successful group was LP in both enamel and dentine. For the undergraduate student, significant inter-operator variation was found in enamel margins in the XE group, which showed significantly higher microleakage ($P < 0.05$). Significant differences were observed between PB and LP, PB and XE, SB and LP and SB and XE in enamel margins for the undergraduate student. In dentine, microleakage in the LP group was significantly lower than it was in the other groups ($P < 0.05$).

DISCUSSION

The quality of bonding is affected by numerous factors such as variations in resin penetration into the demineralized surface and subsequent polymerization, along with the stresses that develop at the adhesive-dentine interface during curing and function. All these variables might be influenced by the operator and are likely to cause variations in results.[13,17] Working steps, such as the etching of enamel and dentine, drying of the cavity, application of adhesive systems-composites and light curing, may show differences even between experienced clinicians. In an attempt to control the variables associated with the stresses from polymerization shrinkage, the same resin composite was used for all samples in this *in vitro* study. Previous studies have shown that there is no significant difference in microleakage between buccal and lingual enamel surfaces and buccal and lingual cementum/dentine surfaces.[18] Application technique and waiting time before curing will also affect bonding reliability since resin diffusion is time dependent. The adhesive systems used in this study were applied according to the manufacturers' instructions.

The performance of light-activated restorative materials is related to the effectiveness with which they are polymerized. Depth of cure has been reported to be related to a logarithmic function of the total amount of exposure – the product of light intensity and irradiation time.[19] Operator controlled factors governing the extent of cure include a light source characteristics, irradiation time, increment thickness and correct light guide position during the irradiation.[19,20] All the operators in this study used the same curing light, which was checked before the start of the study.

The need for a moist dentine surface is more important when using acetone-based adhesive systems than water-based adhesive systems,[21,22] because water can rewet and expand a collapsed collagen network.[23,24] Acetone as a solvent is not effective on over-wet dentine.[25] Therefore, utmost care is required with acetone adhesives when air drying the dentine. It was thought that the undergraduate student would have difficulty in obtaining the optimum degree of dentine wetness before applying PB, but there was no significant difference between the operators.

A total of 5 years are required to earn the DDS degree at the school where the study was conducted. Students provide intensive patient care at the clinics in their 4th year. They use both etch-and-rinse and self-etch adhesive systems, but adhesive systems except PB and SB were not used in the dental clinics of this faculty routinely. Miyazaki *et al*.[26] reported that dental students using dental adhesives for the 1st time tended to read the instructions more carefully and to make the bonding specimens more meticulously. Therefore, inexperience can apparently be an advantage. Adebayo *et al*.[12] reported that the operator's skill in handling a material and/or using the test apparatus may affect the measured micro-shear bond strength and operator skills may improve with repeated testing and material use.

Very few reports are available regarding such technique sensitivity issues, especially with regard to the level of experience of the clinicians. Giachetti *et al*.[13] evaluated the influence of the operator's skills on microleakage of Class V restorations using two types of adhesive. Contrary to our study's results, the microleakage score for the one-step self-etch adhesive was better for the student group than for the expert group. Miyazaki *et al*.[26] studied the effect of operator variability on bond strength of dentine, with university based dentists, undergraduate students and general practitioners as subjects. They concluded that technique sensitivity is the main factor in dentine bonding. Sano *et al*.[27] reported that while clinical experience may play a part in the outcome of bond strength testing, material technique sensitivity may be of more consequence in obtaining optimum bonding performance.

In the present study, the etch-and-rinse adhesives tested gave similar results both with the expert operators and the undergraduate student, showing little sensitivity to operator skill. On the other hand, although the self-etch adhesive did not require any preliminary etching and this reduces the margin of error by the undergraduate student, two of the self-etch adhesives tested (XE, LP) were especially sensitive to operator skill and demonstrated their efficacy when used by the expert operators. The present study showed that the results are more dependent on the operator and interactions between the operator and materials, rather than the choice of material. Therefore the null hypothesis tested has to be rejected. As this was an *in vitro* study, further clinical studies should be conducted to confirm the clinical validity of these results.

CONCLUSION

Under the limits of this methodology, it may be concluded that microleakage of adhesive systems might vary according to the operator's experience.

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