E. U. Celik*, E. Kucukyilmaz**, S. Savas**

Faculty of Dentistry, Izmir Katip Celebi University, Izmir, Turkey
**Department of Restorative Dentistry*
***Department of Pediatric Dentistry*

e-mail: esrauzer@yahoo.com

Effect of different surface pre-treatment methods on the microleakage of two different self-adhesive composites in Class V cavities

ABSTRACT

Aim *To evaluate the effect of different surface pre-treatment methods on the microleakage of self-adhesive flowable composites (SAFCs) in comparison with a conventional flowable composite applied with an etch-and-rinse adhesive system.*
Materials and methods *One hundred and thirty-five standardised Class V cavities were randomly divided into nine groups: (1) three-step etch-and-rinse adhesive (Optibond FL - Kerr, Orange, USA)/flowable composite (Clearfil Majesty Flow - Kuraray, Tokyo, Japan) (E&Ra/flowC); (2) Fusio Liquid Dentin (Pentron Clinical, Orange, USA); (3) Er:YAG Laser/Fusio Liquid Dentin (Er&Las/Fusio Liquid Dentin); (4) Phosphoric Acid/Fusio Liquid Dentin (PhosA/Fusio Liquid Dentin); (5) Polyacrylic Acid/Fusio Liquid Dentin (PolyA/Fusio Liquid Dentin); (6) Vertise Flow (Kerr, Orange, USA); (7) Er:YAG Laser/Vertise Flow (Er&Las/Vertise Flow); (8) Phosphoric Acid/Vertise Flow (PhosA/Vertise Flow); (9) Polyacrylic Acid/Vertise Flow (PolyA/Vertise Flow). After thermocycling and immersion in a 0.5% basic fuchsin, the restorations were evaluated under a stereomicroscope (n = 30). The data were statistically analysed ($\alpha = 0.05$).*
Results *Both SAFCs showed higher leakage scores than E&Ra/flowC in enamel and dentin ($p < 0.05$). Vertise Flow showed lower leakage than Fusio Liquid Dentin in dentin ($p<0.05$). Pre-phosphoric acid etching reduced the microleakage scores of Fusio Liquid Dentin in both enamel and dentin ($p < 0.05$), while all surface pre-treatment methods led to a significant reduction in the microleakage scores of Vertise Flow at the enamel margin ($p < 0.05$).*
Conclusion *Pre-etching of enamel and dentin by phosphoric acid may be satisfactory in improving the sealing ability of Fusio Liquid Dentin, while phosphoric acid or polyacrylic acid etching or laser irradiation may be used to improve the adhesion of Vertise Flow to enamel.*

Keywords *Acid etching, Laser irradiation, Microleakage, Self-adhesive flowable composite*

Introduction

Increasing demand for aesthetic restorations has led dental researchers to focus on the development of materials that mimic the appearance of natural teeth. Among these, composite resins are the first choice to treat anterior and posterior teeth, due to their ability to bond to the dental structure and their better aesthetic appearance [Guray et al., 2013; Geurtsen et al., 1997]. With the development of flowable composites in the late 1990s, they became more popular than conventional resin composites due to their enhanced flow capacity and easy handling properties, especially for Class V restorations [Ozgunaltay and Gorucu, 2005; Sadeghi et al., 2009].

Recently, self-adhesive flowable composites (SAFCs) have been introduced as a new class of restorative material in adhesive dentistry. Today, there are only two available products in the market for clinical use: Vertise Flow and Fusio Liquid Dentin. Their resin matrix contains acidic functional adhesive monomers mediating bonding with dental hard tissues and, therefore, separate etching and additional bonding are not required. SAFCs have been mainly advertised for the restoration of small Class I, Class III and V cavities, for cavity lining, and for use as a pit and fissure sealant. Although simplification of the clinical procedures and limiting handling errors are seen to be major advantages of these materials, the success of SAFCs is reported, to a great extent, to be product-dependent [Van Meerbeek et al., 2010].

The most common reason for failure in composite restorations is the occurrence of secondary caries caused by the microleakage of microorganisms through the resin/tooth interface [Van Meerbeek et al., 2010]. Therefore; microleakage is a very important factor affecting the long-term clinical performance of composites. The microleakage characteristic of a material is dependent on (a) its ability to bond to tooth substances, and (b) the strength of the adhesive layer, which must be resistant to polymerisation shrinkage and thermal stresses [Feilzer et al., 1987; Fortin et al., 1994]. An area of significant interest is understanding if the margin quality of SAFCs is sufficient for preventing microleakage during clinical service, because the quality of the restoration margin of SAFCs may be dissatisfactory as a separate etching step is not included and as SAFCs are not as flowable as bonding agents. Furthermore, the potential hydrophobic-hydrophilic discrepancy between the composite and tooth substrate may cause an insufficient bond [Poitevin et al., 2013]. In this situation, polymerisation shrinkage and thermal stresses may result in the failure of the adhesive layer, which may, in time, lead to microleakage.

The adhesion of self-adhesive cements, which were the first marketed self-adhesive resin-based materials, to enamel and dentin was found to be improved by treatment using phosphoric acid and laser irradiation, and polyacrylic acid, respectively [Pavan et al., 2010; Radovic et al., 2008; Hosseini et al., 2008]. These methods may also improve the adhesion of SAFCs to enamel and dentin, and any success in improving SAFC adhesion to dental tissues will facilitate their use in routine clinical services. The literature provides limited information regarding the microleakage characteristics of the two available SAFCs and the effects of well-known pre-treatment methods, including acid etching and laser irradiation, on their sealing ability. Therefore, the aim of this in vitro study was to evaluate the effect of different surface pre-treatment methods on the microleakage of SAFCs in comparison with a conventional flowable composite applied with an etch-and-rinse adhesive system. The tested null hypothesis is that no statistical differences exist among the microleakage scores of flowable composites applied with different adhesive approaches at the enamel and dentin margins, regardless of any surface pre-treatment methods.

Materials and methods

In this study, two SAFCs (Fusio Liquid Dentin and Vertise Flow) and a conventional flowable composite (Clearfil Majesty Flow, Kuraray, Japan) applied with an etch-and-rinse adhesive system (Optibond FL, Kerr, Orange, CA, USA) were used. Furthermore, three different surface pre-treatment methods (i.e., involving the use of 37.5% phosphoric acid, 20% polyacrylic acid, and Er:YAG laser irradiation) were applied to improve the marginal integrity of the tested composites. The chemical composition, manufacturer, batch numbers, and application procedures of the tested materials are presented in Table 1.

The present study was approved by the Medical Ethics Committee of the Izmir Katip Celebi University, Izmir, (Turkey), under report no. 2014/72. Sixty-eight sound, caries-free human premolar teeth, extracted due to periodontal problems or for orthodontic reasons, were used. The teeth were cleaned with pumice, stored in a 0.1% thymol solution at 4°C and used within 1 month of extraction. Two standardised Class V cavities (3 mm height, 2 mm width, and 2 mm depth) were prepared both on buccal and lingual/palatinal palatal surfaces of the teeth using a round-nosed fissure-type diamond bur (#856L; Brasseler USA Inc., Savannah, USA) at a high speed with oil-free water-spray cooling by a single operator. The depth of the cavities was measured with

	Chemical composition	Application Methods
Fusio Dentin Liquid (#4447169, Pentron Clinical, Orange, CA, USA)	UDMA, TEGDMA, HEMA, 4-MET, nano-sized amorphous silica, silane treated barium glass, minor additives, photo curing system	Dispense a 1 mm increment on the briefly air-dried surface and agitate for 20 s prior to light curing for 10 s; syringe additional material in increments of 1.5–2 mm and light cure for 10 s.
Vertise Flow (#4824705, Kerr, Orange, CA, USA)	GPDM, HEMA; pre-polymerized filler, 1 µm barium glass filler, nano-sized colloidal silica, nano-sized ytterbium fluoride	Dispense a thin layer (<0.5 mm) on a forcefully dried surface; use an applicator with a brushing motion for 15–20 s; light cure for 20 s; syringe additional material in increments of less than 2 mm and light cure for 20 s.
OptiBond FL (#4856729, Kerr, Orange, CA, USA)	Etching: 37.5% phosphoric acid, silica thickener Primer: HEMA, GPDM, PAMM, ethanol, water, photo-initiator Bond: TEGDMA, UDMA, GPDM, HEMA, Bis-GMA, filler, photo initiator	Etch for 15 s; rinse for 15 s; gently air dry for 3 s; apply primer with light brushing motion for 15 s; air dry for 5 s; apply adhesive with light brushing motion for 15 s; air thin for 3 s; light cure for 20 s.
Gel Etchant 37.5% phosphoric acid (#5062962, Kerr, Orange, CA, USA)	37.5% ortophosphoric acid, silica thickener	Etch for 15 s; rinse thoroughly for 15 s and dry.
Gel Etchant 20% polyacrylic acid (#1305271, GC, Tokyo, Japan)	20% polyacrylic acid, distilled water, aluminum chloride hydrate	Etch for 10 s, rinse thoroughly with water and dry.

*UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate HEMA: Hydroxyethyl methacrylate, 4-MET: 4-methacryloxyethyl trimellitic acid, GPDM: glycerophosphoric acid dimethacrylate, Bis-GMA: Bisphenol A glycidyl methacrylate, PAMM: Phthalic acid mono ethyl methacrylate

TABLE 1 Chemical composition, application procedures and batch numbers of the tested materials.

a periodontal probe, and the width of the cavities was measured with a caliper. The occlusal margin of the cavity was on the enamel, while the gingival margin was located on cementum/dentin, 1 mm below the cemento-enamel junction. Following preparation, the specimens were divided into 9 groups (15 cavities each) according to the tested materials and surface pre-treatment methods.

1. Three-step etch-and-rinse adhesive/flowable composite (E&Ra/flowC) (Control): Gel Etchant (37.5% phosphoric acid) / Optibond FL / Clearfil Majesty Flow.
2. Fusio Liquid Dentin: Fusio Liquid Dentin without any surface pre-treatment.
3. Er:YAG Laser/Fusio Liquid Dentin (Er&Las/Fusio Liquid Dentin): Laser irradiation (Er:YAG laser/SP Mode/120 mJ/10 Hz/Non-contact)/Fusio Liquid Dentin.
4. Phosphoric Acid/Fusio Liquid Dentin (PhosA/Fusio Liquid Dentin): Gel Etchant (37.5% phosphoric acid)/ Fusio Liquid Dentin.
5. Polyacrylic Acid/Fusio Liquid Dentin (PolyA/Fusio Liquid Dentin): Gel Etchant (20% polyacrylic acid)/Fusio Liquid Dentin.
6. Vertise Flow: Vertise Flow without any surface pre-treatment.
7. Er:YAG Laser/Vertise Flow (Er&Las/Vertise Flow): Laser irradiation (Er:YAG laser/SP Mode/120 mJ/10 Hz/Non-contact)/Vertise Flow.
8. Phosphoric Acid/Vertise Flow (PhosA/Vertise Flow): Gel Etchant (37.5% phosphoric acid)/Vertise Flow.
9. Polyacrylic Acid/Vertise Flow (PolyA/Vertise Flow): Gel Etchant (20% polyacrylic acid)/Vertise Flow.

All cavity surfaces were subjected to surface pre-treatment methods. The flowable composites and adhesive systems were applied according to the manufacturers' instructions and light-cured with an LED curing unit (Valo, Ultradent Products Inc., South Jordan, UT, USA), set at 1200 mW/cm^2 (Table 1). The restorations were finished with diamond burs at a low speed using an air-water spray and were polished with abrasive discs (OptiDisc System, Kerr Corporation, Orange, CA, USA). The specimens were stored in distilled water at 37°C for 24 h.

After the restoration procedures, the specimens were subjected to thermocycling (Nova Co., Konya, Turkey) for 1000 cycles at 5°C and 55°C with a dwell time of 30 s in each bath, and a transfer time of 15 s. After thermocycling, the root apices of the teeth were sealed with a composite resin to prevent infiltration of the dye solution through this area. The teeth were covered with two layers of nail varnish leaving a 1 mm uncovered area around the margins of restorations. The sealed specimens were immersed in a 0.5% basic fuchsin solution for 24 h at room temperature. Specimens were rinsed in running water and sectioned first mesio-distally and then parallel to the long axis bucco-lingually with a slow-speed diamond saw (Buehler, Inc., Lake Bluff, IL, USA) under a water spray. Two 0.5 mm slices were prepared from the distal and mesial sides of each cavity. The sectioned restorations were examined under a stereomicroscope (Olympus SZ61, Olympus Optical Co®, Tokyo, Japan) at 20× magnification by two blinded examiners who were calibrated prior to the study. Dye penetration at the resin/tooth interface of the enamel and dentin margins was scored using a four-point scale as follows: 0: no dye penetration; 1: dye penetration up to one half of the enamel or dentin wall; 2: dye penetration greater than one half of the enamel or dentin wall; 3. dye penetration including the axial wall.

Statistical analysis

The microleakage scores were analysed using IBM SPSS Statistics version 20.0 statistical package (SPSS, Chicago, IL, USA). The Kruskal–Wallis non-parametric test was used to compare the microleakage scores of study groups, while Mann-Whitney U tests were performed for binary comparisons. The Wilcoxon Signed-Rank test was applied to compare the microleakage scores between the enamel and dentin margins for each group ($\alpha = 0.05$).

Results

The frequencies of microleakage scores at the enamel and dentin margins for each group are shown in Table 2. Descriptive statistics and results of statistical comparisons between study groups at the enamel and dentin margins are presented in Table 3.

At the enamel margins, no significant differences were observed between the microleakage scores of Vertise Flow and Fusio Liquid Dentin; however, they showed significantly higher leakage scores than E&Ra/flowC ($p < 0.05$). Pre-phosphoric acid etching of the enamel reduced the microleakage scores of Fusio Liquid Dentin ($p < 0.05$). PhosA/Fusio Liquid Dentin also produced scores comparable to those of E&Ra/flowC. In contrast, all surface

Groups	Enamel				Dentin			
	0	1	2	3	0	1	2	3
E&Ra/flowC (Control)	23	5	2	0	16	12	1	1
Fusio Liquid Dentin	10	13	4	3	4	15	9	2
Er&Las/Fusio Liquid Dentin	12	16	2	0	2	19	6	3
PhosA/Fusio Liquid Dentin	16	13	1	0	11	17	2	0
PolyA/Fusio Liquid Dentin	9	14	3	4	2	13	4	11
Vertise Flow	12	15	2	1	7	20	2	1
Er&Las/Vertise Flow	24	5	0	1	7	18	1	4
PhosA/Vertise Flow	15	13	2	0	11	9	3	7
PolyA/Vertise Flow	19	8	2	1	5	19	3	3

TABLE 2 Frequency of microleakage scores at the enamel and dentin margins.

Group	Mean (SD)	Median (IQR)	Min-Max	Significance	(p < 0.05)
Enamel	E&Ra/flowC (Control)	0.30 (0.60)	0 (0)	0-2	A, D
	Fusio Liquid Dentin	1.07 (1.02)	1 (2)	0-3	B, E
	Er&Las/Fusio Liquid Dentin	0.67 (0.61)	1 (1)	0-2	B, C, E, F
	PhosA/Fusio Liquid Dentin	0.50 (0.57)	0 (1)	0-2	C, D, F
	PolyA/Fusio Liquid Dentin	1.07 (0.98)	1 (1)	0-3	B
	Vertise Flow	0.80 (0.81)	1 (1)	0-3	B, C
	Er&Las/Vertise Flow	0.27 (0.64)	0 (0)	0-3	A
	PhosA/Vertise Flow	0.57 (0.63)	0.5 (1)	0-2	D, E, F
	PolyA/Vertise Flow	0.50 (0.78)	0 (1)	0-3	A, F
Dentin	E&Ra/flowC (Control)	0.57 (0.73)	0 (1)	0-3	a
	Fusio Liquid Dentin	1.43 (0.82)	1 (1)	0-3	b, c
	Er&Las/Fusio Liquid Dentin	1.33 (0.76)	1 (1)	0-3	b, c, d, e, f
	PhosA/Fusio Liquid Dentin	0.70 (0.60)	1 (1)	0-2	a, f
	PolyA/Fusio Liquid Dentin	1.80 (1.03)	1.5 (2)	0-3	c
	Vertise Flow	1.03 (0.61)	1 (0)	0-3	d, e
	Er&Las/Vertise Flow	1.07 (0.91)	1 (0.25)	0-3	e, f
	PhosA/Vertise Flow	1.20 (1.19)	1 (2.25)	0-3	b, e, f
	PolyA/Vertise Flow	1.13 (0.82)	1 (0)	0-3	b, e, f

SD: Standard deviation, IQR: Interquartile range
Different capital letters label statistically significant differences in enamel leakage scores.
Different small letters label statistically significant differences in dentin leakage scores.

TABLE 3 Descriptive statistics and statistical comparisons between study groups.

pre-treatment methods led to a significant reduction in the microleakage scores of Vertise Flow ($p < 0.05$), and all these groups (Er&Las/Vertise Flow, PhosA/Vertise Flow, and PolyA/Vertise Flow) produced leakage scores similar to those of E&Ra/flowC.

At the dentin margins, Vertise Flow showed lower leakage scores than Fusio Liquid Dentin, while both of them showed significantly higher leakage scores than E&Ra/flowC ($p < 0.05$). Phosphoric acid etching reduced the microleakage scores of Fusio Liquid Dentin bonded to dentin ($p < 0.05$), and this group showed similar scores to those of E&Ra/flowC. However, Er&Las/Vertise Flow, PhosA/Vertise Flow, and PolyA/Vertise Flow combinations had higher leakage scores than Vertise Flow and E&Ra/flowC ($p < 0.05$).

Intra-group comparison of microleakage at the enamel and dentin margins by the Wilcoxon Signed-Rank test did not reveal significant differences in groups E&Ra/flowC, Vertise Flow, and Fusio Liquid Dentin, although microleakage at the dentin margins was significantly higher than that at the enamel margins in the other groups ($p < 0.05$).

Discussion

Microleakage is still a major problem, and the primary reason for failure of composite resin restorations. Because of their widespread clinical use, many studies have investigated the microleakage of different composite materials; however, there are few studies regarding the microleakage of SAFCs and the effect of different surface pre-treatments on their leakage characteristics [Rengo et al., 2012; Bektas et al., 2013; Eliades et al., 2013]. Therefore, the main objective of this study was to assess the microleakage of two available SAFCs, and to evaluate the effect of different surface pre-treatment methods on the microleakage of SAFCs in enamel and dentin.

In the present study, Class V cavities were used to assess microleakage, as their cavity margins are located in both enamel and dentin. In the oral cavity, the restoration and tooth shrink and expand at different rates, causing gaps where microleakage can occur [Manhart et al., 2011; Sensi et al., 2004]. To simulate oral conditions, the teeth were subjected to thermocycling after the restorative procedures in this study.

The most widely accepted method for evaluating the microleakage of restorations is the dye-penetration test. Common dyes for this test include basic fuchsin (0.5–2%), methylene blue (0.2–2%), silver nitrate (50%), crystal violet (0.05%), erythrocin (2%), and Rhodamine B (0.2%) [Feilzer et al., 1987; Fortin et al., 1994, Poitevin et al., 2013, Kemp-Scholte and Davidson, 1989; Heping et al., 2002; Gordan et al., 1998]. In this study, a basic fuchsin dye solution was used for the assessment of microleakage, as it provides a better correlation with SEM quantitative marginal analysis than methylene blue does [Tay et al., 2005].

Based on the results of the present study, the null hypothesis was rejected. No significant differences were observed between the microleakage scores of SAFCs in enamel, while Vertise Flow showed lower leakage scores than Fusio Liquid Dentin in dentin. SAFCs produced significantly higher leakage scores than E&Ra/flowC at both enamel and dentin margins. The reason for the differences between SAFCs and E&Ra/flowC may be explained by three facts: insufficient removal of the smear layer, inadequate micromechanical retention between the restoration and tooth structures caused by the lower etching capacity of the SAFCs, and possible lower flowability of SAFCs compared to dentin bonding agents. The separate phosphoric acid etching step in etch-and-rinse systems increases the surface energy of the enamel surface by removing the smear layer and forms micro-retentive irregularities on the enamel surface [Devarasa et al., 2012]. Furthermore, dentin bonding agents are more flowable, and, as a result, may wet better both enamel and dentin surfaces. Even though there are a considerable number of studies on the adhesion of self-adhesive resins [Lührs et al., 2010; Cantoro et al., 2008; Dos Santos et al., 2014], there are few studies on the bond strength or sealing ability of SAFCs [Fu et al., 2013]. In the articles on self-adhesive cements, their adhesion to enamel appeared to be weaker than that of their counterparts used with etch-and-rinse adhesives [Lührs et al., 2010; Dos Santos et al., 2014], however, the adhesion to dentin was found to be relatively product-dependent [Fu et al., 2013]. When a similar bonding strategy of self-adhesive cements was applied to composite resins, different results were reported about their adhesion characteristics [Poitevin et al., 2013; Rengo et al., 2012]. Similar to the present study, Poitvein et al. [2013] reported that the bonding effectiveness of SAFCs (Vertise Flow and Fusio Liquid Dentin) was lower than that of the flowable composite used with etch-and-rinse system in bur-cut dentin. However, Rengo et al. [2012] supposed that the sealing ability of Vertise Flow was similar to that of an etch-and-rinse system in enamel and dentin. The result of this previous work is different from that of the present study possibly because of the study design; Rengo et al. [2012] did not use a thermocycling process for aging, which may increase the bond failure at the resin/enamel interface due to thermal stresses and water sorption. SAFCs take up water and plasticise over time, as they include functional acidic monomers that significantly increase the hydrophilicity of the resin [Wei et al., 2012]. The possibility for debonding of fillers and degradation of the filler-matrix bond due to the absorption of water increases the hydrophilicity of the resin used [Suyama et al., 2013].

SAFCs used in this study have different acidic functional monomers, composition, and rheological properties. Vertise Flow includes glycerol phosphate dimethacrylate (GMPD) as a functional monomer, whereas Fusio Liquid Dentin is composed of 4-methacryloxyethyltrimetellic acid (4-MET). Even though Fusio Liquid Dentin has a higher flowability than Vertise Flow and 4-MET has a good chemical bonding potential to hydroxyapatite, Fusio Liquid Dentin showed higher leakage than Vertise Flow in dentin margins. In contrast, previous studies found that Fusio Liquid Dentin bonded better to dentin than Vertise Flow did [Poitevin et al., 2013; Fu et al., 2013]. The reason for the differences in results may also be ascribed to the aging procedure used in the present study, as the previous studies measured the immediate bond strength of SAFCs without considering aging. Vertise Flow exhibited excess water uptake, and in a previous study, its hardness value increased even after 1 week in water storage [Eliades et al., 2013]. The hydroscopic dimensional change in Vertise Flow was reported to be significantly higher than that in Fusio Liquid Dentin, which may decrease the polymerisation shrinkage stresses in the adhesion surface [Wei et al., 2013]. Furthermore, Vertise Flow contains fluoride ions that were shown in previous studies to increase bond durability after aging in water. The reason for the improvement in bond strength may be the reaction of fluoride with ingredients beneath the adhesive layer to remineralise the dentin substrate [Shinohara et al., 2009; Ansari et al., 2008]. When self-adhesive resins are used, partially demineralised, non-infiltrated zones of dentin may be formed [Carvalho et al., 2005]. It was claimed that the acidic monomers may form spaces that contain products formed from dissolved calcium and phosphate ions during self-etching. Accordingly, if the fluoride-releasing resin is preferred, the fluoride may be released to those spaces and the future demineralisation of the dental hard tissues may be eliminated by a possible reaction of the fluoride with the other products [Shinohara et al., 2009]. Similar effects might have occurred with SAFCs including fluoride, which has the potential to protect the adhesion interface between a tooth and restoration after aging.

The sealing potential of Fusio Liquid Dentin was significantly increased by pre-etching of the enamel with phosphoric acid compared to that of E&Ra/flowC. On the other hand, all surface pre-treatment methods improved the adhesion of Vertise Flow to enamel. These results agree with those of Eliades et al. [2013] who reported that acid-etching with phosphoric acid produced better adaptation and reduced microleakage in Vertise Flow and Fusio Liquid Dentin. The removal of the smear layer and the micro-irregularities on the enamel surface are the critical issues in enamel adhesion [Poitevin et al., 2013]. Phosphoric acid etching seems to be best alternative for improving adhesion to enamel due to its good ability to remove the smear layer as well as its high demineralisation ability to form microscale irregular areas. The other methods also significantly decreased the leakage scores in Vertise Flow; such differences may result from the GPDM monomer, which highly acidic due to its acidic phosphate group for etching the tooth structure [Poitevin et al., 2013]. In a previous study, Vertise Flow was shown to open the dentin tubules and expose the microporous collagen fibrillar network, which is similar to the effect of the etch-and-rinse approach using phosphoric acid [Poitevin et al., 2013; Fu et al., 2013]. As Vertise Flow has a considerably high acidity due to its functional monomer, the other surface pre-treatment methods improve its sealing ability to enamel, irrespective of their ability to remove the smear layer and to produce irregularities on the surface.

Among the different surface pre-treatment methods used in the present study, pre-etching of dentin by phosphoric acid improved the sealing of Fusio Liquid Dentin similar to that of the E&Ra/flowC. However, none of the methods succeeded to reduce the leakage in dentin margins of Vertise Flow restorations. This may in part be ascribed to the wettability of Fusio Liquid Dentin due to its high flowability; in order to provide better adhesion, the resin should diffuse into the spaces between collagen fibres that were produced by the demineralisation of hydroxyapatite during acid etching [Poitevin et al., 2013]. Fusio Liquid Dentin seemed to be more suitable than Vertise Flow in achieving this penetration after phosphoric acid etching.

Conclusion

Within the limitations of this *in vitro* study, it can be concluded that SAFCs' sealing ability is lower than that of the conventional flowable composite applied with an etch-and-rinse adhesive system in enamel and dentin when additional retention is not provided. Pre-etching of enamel and dentin by phosphoric acid may be satisfactory to improve the sealing ability of Fusio Liquid Dentin, while pre-etching by phosphoric or polyacrylic acid, or laser irradiation may be used to improve the adhesion of Vertise Flow to enamel.

Conflict of Interest

The authors deny any conflicts of interest.

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