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Comparison of marginal adaptation of Class II cavities restored with bulk-fill and conventional composite resins using different universal bonding agent application strategies

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ABSTRACT

Background: This *in vitro* study was conducted to compare the effect of universal bonding application strategy (i.e., self-etch and etch-and-rinse) on marginal adaptation of bulk-fill and conventional composite resins in Class II restorations.

Materials and Methods: In this *in vitro* study sixty sound premolars extracted for orthodontic reasons were selected. The samples were allocated to four groups based on the universal bonding application strategy (self-etch and etch and rinse) and type of composite (bulk-fill and conventional). In each group, boxes were prepared with a depth of 4 mm on the mesial surfaces. Finally, the marginal adaptation of the samples was evaluated under a stereomicroscope. Two-way ANOVA was used to compare the marginal adaptation data in the study. Statistical significance was set at $P < 0.05$.

Results: Considering the type of universal bonding application strategy, there was a statistically significant difference in marginal adaptation. Etch-and-rinse strategy showed better marginal adaptation compared to self-etch strategy ($P < 0.001$). However, there was no statistically significant difference in marginal adaptation between the two composite resins ($P = 0.829$). Furthermore, the interaction between the two factors (type of universal bonding application strategy and type of composite resin) was not statistically significant ($P = 0.629$).

Conclusion: Etch-and-rinse bonding application strategy in both the bulk-fill and conventional composite resins exhibited better marginal adaptation compared to self-etch bonding application strategy. However, the difference of marginal adaptation between the two types of composite resins (bulk and conventional) was not significant.

Key Words: Composite resins, dental bonding, dental marginal adaptation

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INTRODUCTION

In recent years, composite resins have been highly demanded by dentists and patients for anterior and posterior tooth restorations due to several reasons, including esthetics, ability to bond to the tooth structure, good mechanical properties, and ease of use.[1] Clinical success of composite restorations is highly dependent on the efficiency and quality of the bonding system.[1]

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Marginal adaptation is very important for evaluation of the clinical success of different adhesive materials.[1,2] The main problem regarding bonding of composite resins to tooth structure is that all methacrylate-based dental resins undergo shrinkage after free radical reaction and polymerization, which leads to the loss of marginal adaptation and subsequent microleakage, causing discoloration, secondary caries, pulpal inflammation, necrosis, and as a result, failure of the composite restoration.[2]

Recently, dental material manufacturers have introduced new forms of adhesives, referred to as "universal bonding," which can be used with both etch-and-rinse and self-etch strategies.[2,3] In this system, the etchant, primer, and bonding agents have been incorporated in the same bottle, which helps facilitate the process.[3] Even though several studies have been conducted to compare the effects of these two strategies (etch-and-rinse and self-etch) on a variety of bonding properties, their inconsistent results have made the selection of etch-and-rinse or self-etch strategies difficult for clinicians.[3] As reported by several studies, these adhesive systems might lead to inadequate etching and weak enamel bonding; therefore, separate etching using phosphoric acid is recommended before the application of universal bonding agent on enamel.[3] It was demonstrated in a study that the bond strength of universal adhesives to dentin was not significantly different between etch-and-rinse and self-etch strategies.[4] Suzuki *et al*. reported that enamel bonding durability in total-etch strategy was better than the self-etch strategy.[5] However, in a study in 2014, the bond strength of three universal adhesives (Futurabond U' Scotchbond U' All-Bond U) was evaluated using self-etch and total-etch strategies. It was demonstrated that the application of universal bonding agent with etch-and-rinse strategy improved the penetration of the bonding agent into dentinal tubules but did not have any effects on the bond strength compared to the self-etch strategy.[6] Takamizawa *et al*. in 2016 investigated the effects of various etching strategies (self-etch and etch-and-rinse) on shear bond strength and fatigue strength of universal adhesive systems. Three types of adhesives, including Prime and Bond U' Scotchbond U and All-bond U, were used as universal adhesives in this study, and the results showed that the effects of different etching strategies (self-etch and etch-and-rinse) on dentin bond strength depended on the type of the adhesive material used. However, etch-and-rinse strategy did not have any negative effects on dentin bonding properties generally and resulted in better bonding strength in most of the cases compared to the self-etch strategy.[7] In another study, the effects of adopting two different strategies, including self-etch and total-etch, were evaluated on enamel bond strength, and the results showed that compared to the self-etch strategy, bonding strength increased significantly while total-etch strategy was adopted.[8]

On the other hand, bulk-fill methacrylate-based composite resins were introduced for tooth-colored restoration of posterior teeth due to greater durability of stress and occlusal forces.[9] One-step curing is the most important property of bulk-fill composite resins.[9] Advantages of bulk-fill composite resins include simpler proximal contact restoration, functional properties similar to amalgam, elimination of complicated techniques, reduction of clinical steps, increasing the clinical workspeed, and reducing fatigue for the dentist.[9] One of the major concerns regarding the curing process of thick composite resins is their high shrinkage level and subsequent loss of marginal adaptation in the restoration margin, which is mainly observed in cervical margins.[10] Studies have reported inconsistent results with respect to this subject. A study by Savadi Oskoee *et al*. in 2017 on the evaluation of the effects of bulk-fill composite resins on cervical margin adaptation of Class II restorations showed that bulk-fill composite resins had fewer gaps than conventional composite resins (silorane based) and the gap level of enamel margins was lower than dentin margins in both types of composite resin.[9] In a study on the effects of different types of universal bonding adhesives on the bond strength of bulk-fill and conventional composite resins using etch-and-rinse strategy, no significant difference was observed in the bond strength between these two types of composite resin.[10] However, a study by Tayel *et al*. showed that the level of microleakage in flowable bulk-fill composite resin was less than that in conventional composite resin.[11]

The aim of this study was to investigate the effects of adopting these two different strategies with universal bonding system on marginal adaptation of bulk-fill composite resins compared to a conventional composite resin (as a control group) since no study has investigated the effects of these two different strategies (self-etch and etch-and-rinse) with universal bonding system on marginal adaptation of bulk-fill composite resins.

MATERIALS AND METHODS

Sample size and preparation

To conduct this laboratory interventional study, 60 sound human premolar teeth with almost similar mesiodistal and buccolingual sizes, with no cavities, cracks, restorations, or structural defects (extracted due to orthodontic treatment), were collected from patients after obtaining their consent. According to the results of a study by Pathik *et al.*,[12] sample size was determined at 30 samples for each strategy considering an average difference of marginal adaptation of 0.9 between two groups and with standard deviations of 0.35 and 1.21 and a power of 80%. Therefore, a total of 60 samples were included in the study. The samples were decontaminated and disinfected in 0.5% chloramine solution (Kemika, Zagreb) for 2 h and then stored distilled water at 4°C.

The selected teeth were mounted up to 2 mm under the cementoenamel junction in a plastic cylinder, using self-cured acrylic resin and stored in 4°C distilled water; 4-mm-deep boxes were prepared on the mesial surfaces, using a #4 round diamond bur and a #245 fissure bur (Utsunomiya Inc., Tochigi, Japan) in the mounted teeth using a high-speed handpiece (NSK Co., Tochigi-Ken, Japan) under water-air spray. The burs were changed after preparation of every five cavities.

Dimensions of the prepared cavities were as follows: 4 mm of occlusogingival depth, 4 mm of buccolingual width in the occlusal part and 4.5 mm in the gingival part, 2.5 mm of axial wall width in the occlusal part, and 1.5 mm in the gingival part. The angle of internal lines was round, and the cavosurface angles were approximately 90°. Final dimensions were measured once more and were confirmed by a periodontal probe #UNC15.[1,6]

In the present study, marginal adaptation of the restored cavities in two groups of bulk-fill composite resin, X-tra Fill (Voco, Cuxhaven, Germany), and conventional composite resins, Grandio (VOCO, Cuxhaven, Germany), and universal bonding Futurabond U (VOCO, Cuxhaven, Germany) [Table 1] was compared using two universal bonding strategies (etch-and-rinse and self-etch). Therefore, the mounted teeth were classified into four groups of 15 based on the universal bonding agent application strategy and the composite resin type as follows:

- Group 1: Restoration using X-tra fill bulk-fill composite, etch-and-rinse strategy
- Group 2: Restoration using X-tra fill bulk-fill composite, self-etch strategy
- Group 3: Restoration using Grandio conventional composite, etch-and-rinse strategy
- Group 4: Restoration using Grandio conventional composite, self-etch strategy.

Application of different universal bonding strategies was as follows:

Etch-and-rinse strategy (Groups 1 and 3)

First, 37% phosphoric acid (Pulpdent Corporation, Watertown, USA) was applied for 15 s on the dentin and for 30 s on the enamel and then washed for 30 s by air-water spray to completely remove the phosphoric acid that the prepared tooth surface was not overdried. According to the manufacturer's manual, a bonding layer was applied on the cavity walls for 15 s using a microbrush and the solvent was evaporated using air spray for 5 s and light-cured by Bluephase LED Demetron (MONITEX GT-1200, Taiwan) at a light intensity of 1500 mW/cm^2 for 20 s.

Self-etch strategy (Groups 2 and 4)

Separate etching was not performed in this method. First, the teeth were dried by air spray, and then, the bonding agent was applied according to the manufacturer's manual. A bonding layer was placed on the cavity walls for 15 s using a microbrush, and the solvent was evaporated using air spray for 5 s and light-cured by Bluephase LED Demetron (MONITEX GT-1200, Taiwan) at a light intensity of 1500 mW/cm^2 for 20 s.

The placement condition of two composite types, including bulk-fill and conventional, was as follows:

Conventional composite resin restoration condition (Groups 3 and 4)

In these groups, the composite resin was placed in two 2-mm layers and each layer was light-cured separately for 20 s.

Finally, a contouring bur (DFS DIAMOND GmbH, Germany) and an aluminum oxide disk (3M ESPE, USA) were used for finishing and polishing.

The prepared samples were stored in distilled water 37°C and at room temperature until the next step. Then they were subjected to a thermocyclic procedure (5 ± 5°C/55 ± 5°C, 500 cycles). Finally, the teeth were sectioned into two halves buccolingually, using a diamond disk (Diamond GmbH, DandZ, Berlin, Germany). Marginal integrity

Table 1: Materials used in the study and their components

Material	Type	Composition	Batch number	Manufacturer	Application mode
Grandio	Conventional composite	UDMA, Bis-GMA, mixture of diff. dimethacrylate, silicate fillers, initiators, pigments, amines, and additives	N5844859	Voco, Cuxhaven, Germany	Incremental filling in 2 mm thickness
X-tra Fill	Bulk-fill bismethacrylate	MMA, Bis-EMA, inorganic fillers	1147198	Voco, Cuxhaven, Germany	Bulk filling in 4-6 mm thickness
Futurabond U	Universal Adhesive	Bis-GMA, HEMA, 1,6-hexanediylbismethacrylate, acidic adhesive monomer, UDMA, TEGDMA, MDP catalyst	N915019	Voco, Cuxhaven, Germany	Self-etch and etch and rinse

MMA: Methyl methacrylate; Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate; Bis-GMA: Bisphenol-A-glycidyl methacrylate; UDMA: Urethane dimethacrylate; TEGDMA: Triethyleneglycol dimethacrylate; HEMA: 2-hydroxyethyl methacrylate

of the cervical margin was evaluated under a stereomicroscope (Nikon, Japan) [Figure 1] at ×60, and the photography of selected areas was performed by a digital imaging system (Nikon SMZ-800, Tokyo, Japan). The images were transferred to a computer for measurement of gaps. The gap width was measured at three points using DS Camera software (Control Unit DS-LZ.4.4), and the average width was calculated in micrometers. In the end, the results obtained from different groups were compared to each other.

Statistical analysis

The results of the study were reported using descriptive statistical methods (means ± standard deviations). Independent-samples *t*-test was used for comparison of marginal adaptation between the two universal bonding application strategies for each composite resin type. Two-way ANOVA was used for simultaneous comparison of marginal adaptation of the two composite resin types and the two bonding agent application strategies. Statistical analysis was performed using SPSS 17 (SPSS Inc., Chicago, IL, USA), and $P \leq 0.05$ was considered significant.

RESULTS

The means and standard deviations of gap variable for the two composite resins in terms of the strategy used for application of universal bonding agent are shown in Table 2.

All the data had normal distribution according to the results of Kolmogorov–Smirnov test ($P = 0.543$).

Independent-samples *t*-test was used to estimate the statistical difference of the means of gaps of composite resins (bulk-fill or conventional) for two different universal bonding strategies (self-etch and etch-and-rinse). The results showed significant differences in the mean gaps for bulk-fill composite resin between the two different universal bonding strategies (self-etch and etch-and-rinse). This relationship was also observed in the mean gaps of conventional composite resin between the two different universal bonding strategies, such that the mean gaps of both composite resins in self-etch strategy were greater than the etch-and-rinse strategy ($P < 0.001$) [Table 2 and Figure 2].

Figure 1: Measurement of gap by stereomicroscopy.

Two-way ANOVA was used to evaluate the effects of different types of universal bonding strategies on mean gaps of the two composite resins.

The results of this test showed that:

1. There was no statistically significant difference in the means of gaps in terms of composite resin type ($P = 0.829$)
2. There was a statistically significant difference in the means of gaps in terms of the type of universal bonding agent application strategy, and the mean gap in self-etch strategy was greater than that in the etch-and-rinse strategy ($P < 0.001$)
3. There were no interaction effects between composite resin type and universal bonding agent application strategy. In other words, the effects of universal bonding agent application strategy on mean gap were similar in both types of composite resins ($P = 0.629$).

DISCUSSION

The efficiency and long-term durability of composite resin restorations depend on several factors, including adequate sealing of composite resin interface and

Table 2: Mean and standard deviation of gap variable in the two investigated composites based on universal bonding strategy application

Composite type	Universal bonding application strategy	Mean±SD	*P*
Bulk-fill	Etch-and-rinse	10.44±2.81	<0.001*
	Self-etch	15.60±2.34	
Conventional	Etch and Rinse	9.94±2.78	<0.001*
	Self-etch	15.79±3.04	
Total	Etch-and-rinse	10.19±2.59	<0.001**
	Self-etch	15.69±2.66	

*Independent-samples *t*-test, **Two-way ANOVA. SD: Standard deviation

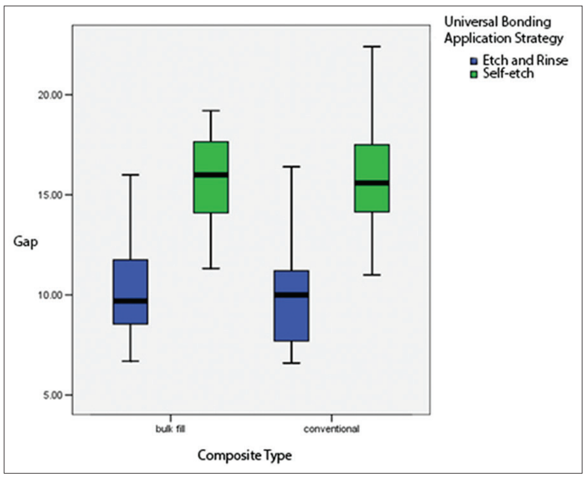

Figure 2: Boxplot chart of the gap variable for the two investigated composite resins in terms of universal bonding agent application strategy (mean gap is expressed in micrometers).

prepared cavity wall. Therefore, studies regarding gap formation mechanisms and related factors are vital and important for improvement and long-term clinical durability of composite resins. If tooth structure bonding is not sufficient, factors resulting from polymerization shrinkage can lead to the formation of gaps at the interface of cavity and resin material. Moreover, the integrity of composite resin restoration margin is influenced by several factors such as cavity size, cutting angles of enamel prisms and dentinal tubules in terms of the cutting site, conditioning situation of dentin tissue, polymerization technique, the type of adhesive system, and restoration material.[13]

Universal or multimode bondings are a new generation of single-step self-etch bonding agents that have been introduced recently. Universal adhesives are called by this name since they can be utilized for a wide range of applications, particularly for restoring the teeth with different substrates in one site. Second, these types of adhesives can be used in both strategies, either with or without separate etching of enamel. Thus, universal adhesives were introduced to overcome the problem of poor efficiency of enamel bonding in self-etch adhesive systems. Anyway, this type of adhesives has been introduced recently, and there is limited information regarding the properties and efficiency of these bonding agents such as the amount of shrinkage resulting from polymerization and marginal adaptation in both self-etch and total-etch strategies.[14]

Unlike conventional composite resins that are placed incrementally in the cavity as 2-mm-thick layers to reduce polymerization shrinkage and achieve proper cure,[15,16] in the bulk-fill technique, the composite resin is placed in the cavity as 4–6-mm-thick layers, and therefore, single-step cavity restoration reduces the chair time significantly. However, there are concerns regarding polymerization shrinkage in this technique.[16]

In the present study, the effects of universal bonding agent application strategy and composite resin type on gap formation of Class II restorations were investigated using two methods, including bulk and incremental.

In this study, the effects of universal bonding agent application strategy on marginal adaptation were investigated and Futurabond U (Voco) universal adhesive was used with two self-etch and total-etch strategies. The results of the current study showed that gap formation was influenced by universal bonding agent application strategy and the gaps in the self-etch strategy were greater than those in the etch-and-rinse strategy. Kaczor *et al*. investigated the effects of two different etching strategies (self-etch and total-etch) on the nanoleakage of 7 different types of universal bonding agents, and consequently, various results were obtained in terms of the type of universal bonding. For instance, nanoleakage was lower with Peak U and G-Bond Plus U universal bonding agents in the etch-and-rinse strategy. However, the leakage was lower for All-Bond U bonding agent in the self-etch strategy, and no significant difference was observed between the two strategies using ScotchBond U and Prime and Bond U bonding agents.[17]

Rasha *et al*. evaluated the nanoleakage of universal bonding agents between the self-etch and total-etch strategies and concluded that the leakage was significantly greater in the self-etch strategy compared to the total-etch strategy, consistent with the results of the present study.[14]

In the present study, Grandio (Voco) conventional composite resin was used in the incremental technique in association with X-tra bulk-fill (Voco) composite resin. The results showed that composite resin type did not affect gap formation and the gaps in the two composite resins were not significantly different. Regarding this subject, studies have shown inconsistent results.

Savadi Oskoee *et al*. showed that bulk-fill composite resins had fewer gaps compared to conventional composite resins due to differences in polymerization mechanisms of these composite resins. The inconsistency between the results of the above-mentioned study and the present study can be due to the difference in the conventional composite resin used. A silorane-based conventional composite resin was used in the study by Savadi Oskoee *et al*.[9]

Similar to the present study, a study in 2016 showed no difference in microleakage between bulk-fill and conventional methods, consistent with the results of the present study.[13]

Furness *et al*. reported that the method of composite resin placement, such as bulk or layer based, did not affect gap formation, which confirms the results of the present study in which X-tra bulk-fill and Grandio composite resins were used with bulk and layer-based techniques, respectively.[18]

Although a great number of studies have been conducted on the effects of universal bonding agent application strategy on several physical properties of bonding agents such as bond durability and microleakage, there is no similar study on the effects of universal bonding agent application strategy and composite resin type simultaneously (bulk-fill and conventional) on gap formation and marginal adaptation. Therefore, the present study is a novelty in this respect. Furthermore, considering the results obtained from this study, it is suggested that the following be investigated in future studies in order to achieve better and more functional results:

1. The interface should be investigated by electron microscopy in future studies
2. Different types of composite resins, including silorane-based composite resins, can be utilized in future works
3. It is better to use different brands of universal bonding agents with different combinations and pH values in future studies.

CONCLUSION

Considering the limitations of the present study and thorough evaluation and analysis of the results, it can be concluded that:

1. The type of universal bonding strategy can influence marginal adaptation, and marginal adaptation in the etch-and-rinse strategy was better than that in the self-etch strategy
2. The type of composite resin (bulk-fill and conventional) did not have significant effects on marginal adaptation.

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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 non-financial in this article.

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