

Comparison of shear bond strength of self-adhering flowable composite with different flowable composites to dentin

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ABSTRACT

Purpose: The purpose of this study was to measure and compare the shear bond strength of a self-adhering flowable resin composite with different flowable composites to dentin. **Materials and Methods:** A total of 48 extracted teeth were divided randomly into four groups, and dentin surfaces were exposed. Following materials were applied to dentin surfaces; Group I: VF (self-adhering flowable composite), Group II: CSE Bond (two-step self-etch adhesive) + CMF (conventional flowable composite), Group III: AB SE (one-step self-etch adhesive) + AF (conventional flowable composite), Group IV: AEO (one-step self-etch adhesive) + FUF (conventional flowable composite). The specimens were subjected to shear loading using a universal testing machine. The type of failure was detected with an illuminated microscope. One-way analysis of variance and Tukey multiple comparison test were used to determine statistical significance differences between groups. **Results:** Mean shear bond strength values were ranked as follows; Group II > Group IV > Group III > Group I. Statistically significant differences were found among all groups ($P < 0.05$). **Conclusion:** Group I; the self-adhering flowable resin composite had the lowest shear bond strength values while Group II; showed the highest shear bond strength among the materials tested.

Key words

Dentin, flowable composite, shear strength

INTRODUCTION

Since the first introduction in dental market, flowable composites have become an integral part of the restorative process. Initially these resins were developed to be used in Class V cavities, but today they have been included in a variety of clinical applications; e.g., small carious lesions, pit and fissure sealants, liners, crown cementation, and other adhesive restorative procedures.^[1,2] They have already been accepted for a wide variety of uses because previous *in vitro* studies have reported that microleakage and the occurrence of voids were reduced by using the flowable composites.^[3,4] However, the limitations of flowable composites are still unknown.

Evaluation for bonding durability is important since the long-term clinical success of tooth colored restorations might be dependent on the stability of the bond between restoration and tooth substrate. Bonding durability of the adhesive system is affected by technique sensitivity; therefore, to reduce the sensitivity, steps required for bonding procedures have been reduced. When selecting an adhesive system, bond strength is one of the significant factors that plays a major role for the long-term clinical success of the restoration. New approaches have been introduced such as self-etch systems for bonding restorative materials to tooth substrate.^[5-7] More recently, the newer formulation has been introduced which is the first self-adhering flowable composite; Vertise™ Flow.

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Vertise flow is a self-adhering, flowable composite resin, whose bonding mechanism based on the adhesive monomer glycerol phosphate dimethacrylate (GPDM). GPDM is a functional monomer that is responsible for etching the tooth structure and also for chemically bonding to the calcium ions within the tooth structure. On the other hand, it has two methacrylate functional groups for copolymerization with other methacrylate monomers to provide increased cross linking density and enhanced mechanical strength for the polymerized adhesive. The resin also contains hydroxyethyl methacrylate, which is used to provide wetting and resin penetration in dentin (Vertise Flow Technical Bulletin). Eliminating the need for a separate adhesive application holds great potential for saving chair time and minimizing handling errors.^[8]

The purpose of this study was to measure and compare the shear bond strength of the self-adhering flowable composite; Vertise™ Flow with different flowable composites used with self-etch bonding agents, to dentin. The following null hypothesis was tested; the self-adhering flowable composite has similar bond strength values with conventional flowable composites.

MATERIALS AND METHODS

Forty-eight extracted caries free permanent molar teeth, which have been stored in distilled water after extraction, were selected for the study. The roots of the teeth were removed and the crowns were embedded into autopolymerizing acrylic resin with buccal surfaces facing up. Enamel surfaces were flattened with a diamond bur until the dentin was exposed. The exposed dentin surfaces were prepared using 400 grit and 600 grit silicon carbide papers. All the samples were divided randomly into four groups ($n = 12$).

Following materials were applied according to the manufacturers' instructions [Table 1] to dentin surfaces by packing the material into a cylindrical-shaped plastic matrix with an internal diameter of 3 mm and height of 2 mm;

- Group I: Vertise™ Flow (Kerr, Orange, CA, USA) self-adhering flowable resin composite,
- Group II: The two-step self-etch adhesive; Clearfil SE Bond (Kuraray, Osaka, Japan) and Clearfil Majesty Flow (Kuraray, Osaka, Japan) conventional flowable composite,
- Group III: One-step self-etch adhesive; All-Bond SE (Bisco, Schaumburg, IL, USA) and Aelite Flo (Bisco, Schaumburg, IL, USA) conventional flowable composite,
- Group IV: One-step self-etch adhesive; Adper Easy One (3M ESPE, St. Paul, MN, USA) and Filtek Ultimate Flow (3M ESPE, St. Paul, MN, USA) conventional flowable composite.

All specimens were cured with LED.G curing light (Woodpecker, Guangxi, P.R. China) and then stored in distilled water in an incubator at 37°C for 24 h. The specimens were subjected to shear loading using the universal testing machine (Lloyd; England). The shear bond strength values were calculated as the ratio of fracture load and bonding area and expressed in megapascals. After load testing, the type of failure was detected under $\times 30$ magnification with an illuminated microscope [Table 2]. One-way analysis of variance and Tukey multiple comparison test were used to determine the significance of differences between groups.

RESULTS

Mean shear bond strength values and the mode of failures were shown, respectively, in Tables 3 and 4.

Mean shear bond strength values were ranked as follows; Clearfil Majesty Flow > Filtek Ultimate Flow > Aelite Flo > Vertise™ Flow. Statistically significant differences were found among all groups ($P < 0.05$).

Type of failures was determined according to Table 2. After shear loading in all groups, type 1 failure (adhesive failure between material and teeth) was mostly observed and it is followed by type 2 failure (partial adhesive failure between material and teeth, and partial cohesive failures within the restorative material).

Failure modes; type 3 (partial cohesive failures within the teeth), type 4 (cohesive failures within the restorative material), and type 5 (mixed failure: Partial adhesive failures within the teeth, and partial cohesive failure between material and teeth) were not observed in any of the groups.

DISCUSSION

Adhesion in dentistry could be stated as the relationship between bonding and stress. The restoration would be successful if the bonding could withstand the stress. Strong and durable bonding between restorative material and tooth substrate are essential when judging mechanical, biological, and esthetic aspects. When compared to enamel bonding, the bonding of resin based restorative materials to dentin has always been more challenging.^[2,7] Therefore in the present study, we aimed to test the bond strength of a self-adhering flowable composite to dentin.

To assess the bond strength of restorative materials, various tests have been presented. Shear bond strength test is comparatively simple, reproducible, and commonly accepted.^[7,9] Accordingly we have used the shear bond strength test. It has been reported that thermocycling has no significant effect on bond

Table 1: Materials used in this study

Product name	Manufacturer	Composition	Instructions for use
Vertise Flow	Kerr, Orange, CA, USA	GPDM adhesive monomer, Prepolymerized filler containing barium glass filler, nano-sized colloidal silica, nano-sized ytterbium fluoride	Brush a thin layer (<0.5 mm) of Vertise Flow for 15-20 s, Light cure for 20 s. Build additional layers (2 mm or less) then light cure for 20 s
Clearfil SE Bond	Kuraray, Osaka, Japan	Primer: 10-MDP, HEMA, hydrophilic dimethacrylate, photoinitiator, water Bond: 10-MDP, Bis-GMA, HEMA, hydrophilic dimethacrylate, microfiller	Apply primer for 20 s; gently air blow; apply bonding agent; light cure for 10 s
Clearfil Majesty Flow	Kuraray, Osaka, Japan	Triethylene glycol dimethacrylate, Hydrophobic aromatic dimethacrylate, Silanated barium glass filler, Silanated colloidal silica, dl-Camphorquinone, Accelerators, Pigments, Others	Place the product (1-1.5 mm) into the cavity. Light cure each increment for 20 s
All-Bond SE	Bisco, Schaumburg, IL, USA	Ethanol, benzenesulfonate acid na salt 2-hydroxyethyl methacrylate water, BPDM, acidic monomers camphorquinone	Apply to the dry preparation, then agitate for 5-10 s. Gently air dry 5 s. Light cure for 10 s
Aelite Flo	Bisco, Schaumburg, IL, USA	Ethoxylated bis a dimethacrylate triethylene glycol dimethacrylate camphorquinone, bisgma barium glass, fillers ethyl-4-dimethylaminobenzoate	Place 1-2 mm increments of composite into the cavity preparation. Light cure each increment for 20 s
Adper Easy One	3M ESPE, St Paul, MN, USA	2-hydroxyethyl methacrylate, Bis-GMA, Methacrylated phosphoric esters, 1,6 hexanediol dimethacrylate, Methacrylate functionalized Polyalkenoic acid (Vitrebond™ Copolymer), Finely dispersed bonded silica filler, Ethanol, Water, Initiators based on camphorquinone, Stabilizers	Apply adhesive to tooth surface for 20 s. Dry the adhesive for 5 s. Light cure for 10 s
Filtek Ultimate Flow	3M ESPE, St Paul, MN, USA	BisGMA, TEGDMA and Procrylat resins, ytterbium trifluoride filler, zirconia/silica cluster filler, silica filler	Place the composite into the cavity (2 mm) Light cure for 20 s

GPDM – Glycero-phosphate dimethacrylate, MDP – Methacryloxydecyl dihydrogen phosphate, HEMA – Hydroxyethyl methacrylate, Bis-GMA – Bisphenol A Glycidyl Methacrylate, BPDM – Biphenyldicarboxylic-acid dimethacrylate, TEGDMA – Triethyleneglycol dimethacrylate

Table 2: Classification of type of failures^[15]

Type of failure
Type 1 : Adhesive failure between material and teeth
Type 2 : Partial adhesive failure between material and teeth and partial cohesive failures within the restorative material
Type 3 : Partial cohesive failures within the teeth
Type 4 : Cohesive failures within the restorative material
Type 5 : Mixed failure (Partial adhesive failures within the teeth and Partial cohesive failure between material and teeth)

Table 3: Mean shear bond strengths (MPa) and standart deviations of the materials tested

Material	N	Minimum	Maximum	Mean (Std. Deviation)
Vertise™ flow	12	0.36	7.27	2,94 (1,95) ^a
Clearfil majesty posterior	12	10.33	17.79	14,70 (2,47) ^b
Aelite Flo	12	4.85	13.00	8,29 (2,66) ^c
Filtek flow	12	7.54	15.39	12,90 (2,40) ^d

Significant differences between groups with the different superscript letters (P<0.05). MPa – Megapascal

Table 4: Type of failures of the experimental groups

Material	Type 1	Type 2	Type 3	Type 4	Type 5
Vertise™ flow	9	3	-	-	-
Clearfil majesty posterior	9	3	-	-	-
Aelite Flo	8	4	-	-	-
Filtek flow	7	5	-	-	-

strength.^[10,11] In recent years most of the studies did not use thermocycling for shear bond strength,^[12-15] as in the current study we have not included thermocycling into the testing procedures.

The bonding of composite resin to enamel and dentin is provided through the use of an adhesive system. The efficacy of adhesive systems varies significantly among the different brands and types of systems.^[7,16] In the current study; in each group, different brands' products were used as tested materials and also the adhesive system applications were different from each other. According to the manufacturers' recommendation, to have successful dentin bonding procedures, the same manufacturers' dentin adhesive and composite should be used.^[17] In the present study, we have used the dentin adhesive and composites from the same manufacturers'. In Group II, two-step self-etch adhesive was used and this group had the highest bond strength values which is similar to the studies that have reported the superiority of two-step self-etch adhesives.^[7,16,18] As well as; in most of the previous studies, Clearfil SE Bond had the highest bond strength values among the various adhesives tested.^[19-21]

Based on the findings of the present study, the null hypothesis has to be rejected as the self-adhering flowable composite Vertise™ Flow displayed the lowest bond strength among the other flowable composites. In

a previous study evaluating effects of dentin bonding agents on bonding durability of a flowable composite to dentin, researchers reported that there were no significant differences between one-step, two-step, and three-step adhesives in bond strength and concluded that the use of simplified bonding agents did not necessarily effect the bond strength of flowable composites.^[22] Therefore in the present study, we have also as compared to Vertise™ Flow with a two-step self-etch adhesive, although this material carries more similarities with one-step self-etch adhesives.

In the present study, Aeliteflo displayed lower shear bond strength values than the other flowable composites applied with self-etch adhesives. In a previous study investigating the influence of flowable resins on the shear bond strength of orthodontic brackets, Aeliteflo also showed significantly lower values than other conventional flowable composites.^[23]

The residual smear layer disturbs monomer infiltration into underlying dentin and it effects stable adhesion.^[5] Smear layer removal or modification is essential for the formation of a high quality hybrid layer and it provides optimal adhesion to dentin.^[24] For the self-etch adhesives, smear layer modification is dependent on the pH of the primer used.^[25,26] In the present study; Clearfil SE Bond Primer with a pH of 2.0 and All-Bond SE with a pH of 2.2 are regarded as a mildly self-etch adhesives, and Adper Easy One has a pH of 3.5. The self-adhering resin Vertise™ Flow has a pH level of 1.9, according to the manufacturers; the material effectively modifies the smear layer and bonds to the tooth substrate. Although Vertise™ Flow had the most acidic pH among the materials tested; the lowest bond strength values were obtained with this material. According to the results of our study, there is no direct correlation between acidic pH of the material and the bond strength.

In a previous study, the shear bond strength of all-in-one adhesive systems and Vertise™ Flow were evaluated, and the authors have reported that Vertise™ Flow had the lowest bond strength similar to our study results.^[8] The bonding mechanism of Vertise™ Flow relies on the adhesive monomer GPDM, whose phosphate group is responsible for acid etching and chemical bonding with calcium ions of the dental substrate. Mechanical strength is provided to the material by the cross-linking of methacrylate functional groups with other methacrylate monomers (Vertise™ Flow Technical Bulletin). To promote the interaction of the acidic monomers, the company recommends brushing the first layer of material onto the entire cavity surface for 20 s.^[27] However in the present study, active application did not enhance the bond strength of Vertise™ Flow to levels comparable to those of the other materials tested similar to the study of Vichi *et al.* (2013). As Bektas *et al.* explained; adding other fillers could be the reason of the low bond strength of

Vertise™ Flow.^[28] Also Miyazaki *et al.* (1995) stated that filler in the adhesive resin may reduce the wetting of the dentin surface because of the high viscosity and this would decrease the penetration of monomers.^[29] Therefore, the reason of the lowest bond strength values with Vertise Flow, might be the high viscosity and low wettability of the material.

Tuloglu *et al.* have investigated the shear bond strength of Vertise™ Flow with and without application of an adhesive system. The results of the study showed that Vertise™ Flow with an adhesive system had the higher bond strength values than it is used individually and also similar to our study, they have found the bond strength of a conventional flowable resin composite; Filtek Ultimate Flow higher than Vertise™ Flow.^[30]

Similar to the study of Tuloglu *et al.*, Bektas *et al.* have reported in their *in vitro* study, Vertise™ Flow combined with adhesive resin provided stronger dentin bond strength than when it was used individually. Furthermore, in different *in vitro* studies, Vertise™ Flow has displayed lower shear bond strength values than all-in-one adhesive,^[31] etch-and-rinse adhesive and two-step self-etch adhesive systems^[32] similar to our study.

The adhesive failure mode was mostly observed for all tested groups; it could be stated that the material's own cohesive strength was higher than the bond strength between the material and tooth substrate. Only in Filtek Flow group, the number of adhesive and partial cohesive failures was close to each other.

The self-adhering flowable composite; Vertise™ Flow had the lowest shear bond values while Clearfil Majesty Flow showed the highest shear bond strength values among the materials tested, the null hypothesis has been rejected. The bond strength of the materials might be contributed to the adhesive system used with the composite resin. According to the results of our study; we can conclude that minimizing the bonding procedures decrease the bond strength. As well as, according to the manufacturers, the material eliminates additional steps of etching/priming/bonding necessary to bond a resin composite to dentin or enamel, but before application it requires an additional step of brushing a thin layer of the material for 15–20 s and light cure for 20 s. The procedure is similar to the application of one-step self-etch adhesives that displayed higher bond strength values than this material. Further *in vitro* and the clinical studies are needed to evaluate the self-adhering flowable composite; Vertise™ Flow for the long-term success of the restorations.

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Conflicts of interest

There are no conflicts of interest.

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