Are the Flowable Composites Suitable for Orthodontic Bracket Bonding?

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Abstract: The study aims to determine the shear bond strength (SBS) values of different flowable composites (Pulpdent® Flows-Rite, 3M™ Filtek Flow, and Heraeus Kulzer® Flow Line) in comparison with a conventional orthodontic adhesive and the bond failure sites of these composites. Eighty extracted human premolars were divided into four groups of 20 teeth each. Brackets were bonded to the teeth in each test group with different composites, according to the manufacturer's instructions. SBS values of these brackets were recorded (in MPa) using a universal testing machine. Adhesive remnant index (ARI) scores were determined after the failure of brackets. Data were analyzed using analysis of variance (ANOVA), Tukey honestly significant difference, and chi-square tests. SBS values of groups 1 (Transbond XT), 2 (Flows-Rite), 3 (Flow), and 4 (Flow Line) were found to be 17.10 ± 2.48 MPa, 6.60 ± 3.2 MPa, 7.75 ± 2.9 MPa, and 8.53 ± 3.50 MPa, respectively. The results of this study demonstrate that the orthodontic adhesive (Transbond XT) had higher SBS values than the flowable composites. Results of ANOVA revealed statistically significant differences among the groups ($P < .05$). The SBS values were significantly lower in all flowable composite groups than the orthodontic adhesive. ARI scores were significantly different between the orthodontic adhesive and all the flowable groups investigated. The use of flowable composites is not advocated for orthodontic bracket bonding because of significantly lower SBS values achieved. (*Angle Orthod* 2004;74:697–702.)

Key Words: Flowable composites; Shear bond strength; Adhesive failure side

INTRODUCTION

Buonocore[1] introduced the technology that eventually leads to the concept of direct bonding in orthodontics. Ten years later, Newman[2] described a technique for acid-etching enamel to enhance the mechanical adhesion of orthodontic brackets to the teeth. Since then several factors that affect the mechanical adhesion of orthodontic brackets to the teeth have been described.

Recently, a wide variety of visible light–cured orthodontic adhesives have become commercially available. Current trends in orthodontic materials research, focusing on this type of bonding system, suggest that these adhesives provide a convenient means of achieving clinically acceptable results.[3–10] The advantages of visible light–cured orthodontic adhesives are the high early bond strength,[7] minimal extent of oxygen inhibition,[4] and the extended working time for optimal bracket placement.[8]

Filled dental restorative materials were also used as orthodontic adhesives.[9] These materials consist of an organic diacrylate (BIS-GMA), a coupler (silane), and a higher percentage content of inorganic filler (quartz, silica). The inorganic filler makes the material more abrasion resistant, increases the shear bond strength (SBS) values, and decreases the coefficient of thermal expansion to values closer to those of enamel to prevent long-term microleakage.

Ostertag et al[11] designed an experimental study to evaluate the influence of adhesive filler concentration on bond strength, keeping the filler particle size constant. The results of that study indicate that there is an increase in shear and torsional bond strength with increasing concentrations of adhesive filler.

Some authors believe that charged particles in the composite resin limit the free flow of adhesive into the enamel pores, inhibiting the formation of resin tags.[12–14] Others believe that the liquid phase of the composite is present in sufficient amount to flow into the conditioned enamel porosities and act independently of the charged particles. These workers use this as an explanation for the equal size of resin tags obtained when the composite resin or the sealant is applied directly to the conditioned enamel.[15–18]

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Flowable resin composites have been recommended for many clinical uses and have been formulated in a variety of compositions and viscosities to meet various uses.[19] A plethora of new low-viscosity composite resin materials, or flowable composites, have been marketed during the past three years but little has been published about them.

The aim of this study was to test different flowable composites to determine their SBS values in comparison with a conventional bonding adhesive and the site of bond failure of flowable composites.

MATERIALS AND METHODS

Eighty noncarious human premolars, extracted for orthodontic indications, were used in this study. Teeth with hypoplastic areas, cracks, or irregularities of the enamel structure were excluded from the study. The criteria for tooth selection dictated no pretreatment with chemical agents such as alcohol, formalin, and hydrogen peroxide. The extracted teeth were stored in distilled water continuously after extraction. The water was changed weekly to avoid bacterial growth. The sample was randomly divided into four groups of 20 each. Each tooth was mounted vertically in a self-cure acrylic block so that the crown was exposed. The buccal enamel surface of the teeth were cleansed and polished with nonfluoridated pumice and rubber prophylactic cups, washed with water, and dried.

A 37% phosphoric acid gel (3M Dental Products, St Paul, Minn) was used for the acid etching of premolars for 30 seconds. The teeth were rinsed with water for 30 seconds and dried with an oil-free source for 20 seconds. In all etched cases, the frosty white appearance of enamel was present. Standard edgewise premolar stainless steel brackets were bonded to the teeth using the bonding protocols, according to the manufacturer's instructions (product no: ED-STU 418, G&H Wire Company, Greenwood, Ind, US & Canada). The average surface of the orthodontic bracket base used was 14.00 mm^2.

After acid etching, the brackets were bonded in the following manner (Figure 1):

1. Group 1 (Transbond XT): Transbond XT primer was applied to the etched surface in a thin film. Transbond XT (3M Dental Products) adhesive paste was applied to the bracket base, and the bracket was positioned on the tooth and pressed firmly into place. The excess adhesive was removed from around the bracket with a scaler, and the adhesive was light cured from the mesial and distal for 10 seconds each (total time 20 seconds).
2. Group 2 (Flows-Rite): This product is a highly polishable and contains 68% filled by weight and 47% by volume of flowable composite with the corresponding handling and flow characteristics (Table 1). During this procedure, placing primer on the etched enamel surface was not recommended by the manufacturer (Flows-Rite, Pulpdent® Corporation, Watertown, Mass). Flowable composite paste was applied to the bracket base, and the bracket was positioned on the tooth and light cured for 30 seconds from the incisal edge.
3. Group 3 (Flow): Flow (Filtek™, 3M Dental Products) is a low-viscosity, visible light–activated, radiopaque flowable composite. 3M Filtek Flow contains BisGMA and TEGDMA resins. The filler in this composite is zirconia/silica and is loaded 47% by volume (Table 1). According to the manufacturer's instruction, the primer (3M Single Bond Adhesive) was applied to the etched surface in a thin film and light cured for 10 seconds. The bracket was positioned, and the composite was light cured for 20 seconds.
4. Group 4 (Flow Line): Flow Line (Heraeus Kulzer, Dormagen, Germany) is a medium-viscosity, hybrid composite resin, with the same size filler particles as universal hybrid composites. It consists of a lower percentage of filler, resulting in its flowability. It is 62% filled by weight and 41% by volume (Table 1). According to the manufacturer's instruction, primer (Clearfil SE Bond, Kuraray Co, Ltd, Osaka, Japan) was applied to the etched surface in a thin film and light cured for 10 seconds. The bracket was positioned, and the composite was light cured for 20 seconds.

Debonding procedure

The embedded specimens were secured in a jig attached to the base plate of a universal testing machine (Micro 500, Testometric, Maywood Instruments Limited, Basingstoke Hants, UK). A chisel-edge plunger was mounted in the movable crosshead of the testing machine and positioned so that the leading edge aimed the enamel-composite interface before being brought into contact at a crosshead speed of 0.5 mm per minute. The maximum load necessary to debond the bracket was recorded. The force required to take off the brackets was measured in newtons, and the SBS (1 MPa = 1 N/mm^2) was then calculated by dividing the force values by the bracket base area (14 mm^2).

Residual adhesive

After debonding, all teeth and brackets were examined under 10× magnification. Any adhesive remaining after bracket removal was assessed with the adhesive remnant index (ARI)[6,10] and scored with respect to the amount of resin material adhering to the enamel surface. The ARI scale ranges between 5 and 1, with 5 indicating that no composite remained on the enamel; 4 less than 10% of the composite remained on the tooth; 3 more than 10% but less than 90% remained on the tooth; 2 more than 90% of the composite remained; and 1 all the composite remained on the tooth, along with the impression of the bracket base. The ARI scores were used as a more comprehensive means of defining the sites of bond failure between the enamel, the adhesive, and the bracket base.

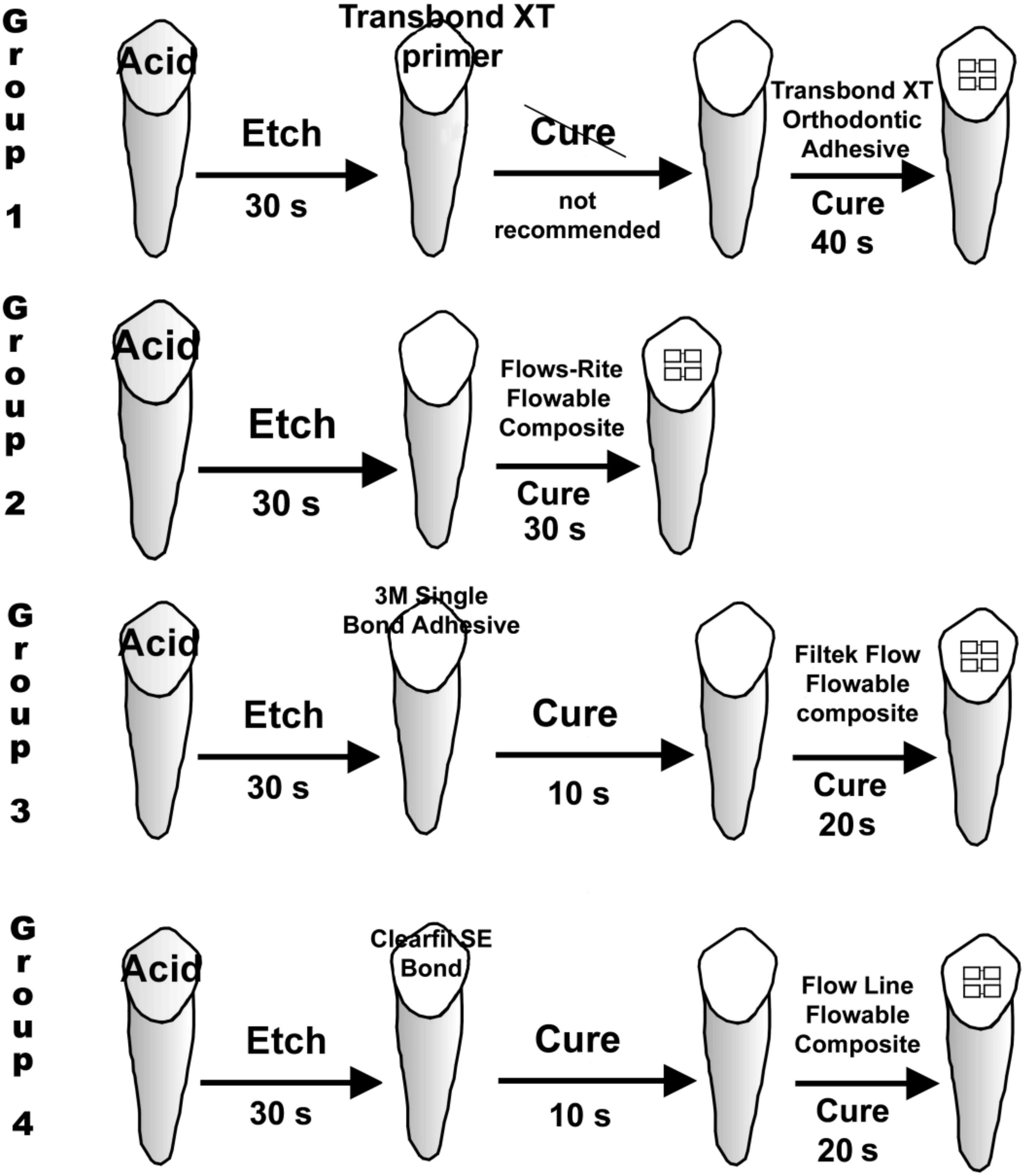

FIGURE 1. Flowchart for the bonding procedure applied.

Statistical method

Descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated for each of the four groups of teeth tested. Comparisons of means were made using analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) tests. The chi-square test was used to determine significant differences in

TABLE 1. Handling and Flow Characteristics of Composites

	Filler Material	Filler Rate By Weight (%)	Filler Rate By Volume (%)	Average Particle Size (μm)
Flows-Rite (Pulpdent)	Glass	68	47	0.7
Filtek Flow (3M)	Zirconia/silica	68	47	1.5
Flow Line (Heraeus Kulzer)	Plastic	62	41	0.7

TABLE 2. Descriptive Statistics of Shear Bond Strength (MPa) of the Four Groups Tested

Groups Tested[a]	*N*	Mean	SD	Range	Test*
Group 1	20	17.10	2.48	12.3–20.7	A
Group 2	20	6.60	3.20	1.7–12.1	B
Group 3	20	7.75	2.90	2.6–13	B
Group 4	20	8.53	3.50	3.2–16.4	B

[a] Group 1, Transbond XT (3M Unitek); group 2, Flows-Rite (Pulpdent); group 3, Filtek Flow (3M); group 4, Flow Line (Heraeus Kulzer).

* Groups with different letters are significantly different from each other.

TABLE 3. Adhesive Remnant Index (ARI) Scores of the Residual Adhesive on Enamel Surface[a]

Groups tested[b]	*N*	1	2	3	4	5
Group 1	20	—	4	5	7	4
Group 2	20	11	8	—	1	—
Group 3	20	17	2	—	—	1
Group 4	20	16	4	—	—	—
		$\chi^2 = 77.602$		$P = .0001$		

[a] ARI scores: 1 = all the composite, with an impression of the bracket base, remained on the tooth; 2 = more than 90% of the composite remained; 3 = more than 10% but less than 90% of the composite remained on the tooth; 4 = less than 10% of composite remained on the tooth surface; 5 = no composite remained on the enamel.

[b] Group 1, Transbond XT (3M Unitek); group 2, Flows-Rite (Pulpdent); group 3, Filtek Flow (3M); group 4, Flow Line (Heraeus Kulzer).

the ARI scores among the different groups. All statistical analyses were performed using the SPSS software package (SPSS for Windows, version 10.0.1, SPSS Inc, Chicago, Ill).

RESULTS

Shear bond strength

The descriptive statistics, including the mean, standard deviation, and minimum and maximum values for each of the four groups, are presented in Table 2. Data were analyzed using ANOVA and Tukey HSD tests. The results of this study demonstrate that group 1 had higher SBS values than the flowable composites. Results of ANOVA revealed statistically significant differences in bond strengths among the various groups tested ($P < .05$). The results of ANOVA and Tukey HSD test are shown in Table 2.

Group 1 had a mean value of 17.10 ± 2.48 MPa, the highest of all test groups. Groups 2, 3, and 4 had mean bond strengths of 6.60 ± 3.20 MPa, 7.75 ± 2.90 MPa, 8.53 ± 3.50 MPa, respectively.

Adhesive remnant index

The residual adhesive on the enamel surfaces was evaluated by the ARI scores, and the results are presented in Table 3. The chi-square test indicated that significant differences ($\chi^2 = 77.602$, $P = .0001$) were present among the various groups. In group 1, some or all the composite remained on the bracket. In groups 2–4, the groups where different composites were applied, 90% or more of the composite remained on the tooth (ARI scores 1 and 2).

DISCUSSION

Most bonding studies use commercially available adhesive systems that have different filler particle sizes, viscosities, and concentrations.[11] This makes comparisons among the groups difficult because of the increased number of variables involved in the adhesive composition. The aim of the present study was to test different flowable composites, in comparison with a conventional light-cure orthodontic bonding adhesive.

The influence of filler concentration on the viscosity remains a clinically important issue, and the clinical application of specially formulated composites must be addressed.[11] The mean SBS values of composites used in this study fell within clinically acceptable ranges. However, flow property is another special feature and is an important clinical consideration that influences both the penetration of the adhesive into the retentive mechanism of the bracket base and the ability of an adhesive to resist bracket drift during direct bonding. Visual and light microscopy evaluation revealed that the composites in this study (particularly, in groups 2, 3, and 4) did not fully penetrate into the retentive mechanism of the bracket bases. However, the clinical acceptability of the flowable composites tested in the present study for direct chair-side bonding of metallic orthodontic brackets appeared to be adequate under their current flow characteristics. Therefore, we believe that the composite had penetrated sufficiently into the retentive pores on the enamel surface.

The mean SBS values of all composites tested were greater than the 5.9 MPa, considered by Reynolds[20] to be adequate for routine clinical use. However, for the flowable composites, the 30–40% failure rate was clinically unacceptable (Table 2). The maximum bond strength recommended for successful clinical bonding is estimated to be 7 MPa.[21] In another study, shear stresses exerted on attachments during orthodontic treatment were reported to range from 1 to 3 MPa,[22] although higher stresses can occur during mastication.[23] Studies have shown that metal brackets bonded with composite resins show bond strengths ranging from 2 to 13 MPa.[23] However, in the current study, the bond strength for Transbond XT, at 17.10 ± 2.48 MPa, was significantly greater than the bond strengths of the other flowable composites, and this was also greater than that observed in some previous studies,[2,24–26] although similar to that found by Sinha et al.[27] However, clinical conditions may significantly differ from an in vitro setting. Moreover, heat and humidity conditions of the oral cavity are highly variable. Because of the probable differences between in vivo and in vitro conditions, a direct comparison cannot be made with the findings of the other studies.

Frankenberger et al[28] indicated that the flowable composites of thinner viscosity may bond to enamel adequately without the requirement of an intermediate bonding resin. Flows-Rite composite displayed the lowest minimum value in terms of bond strength among all composites, suggesting that application of this material may need a more sensitive technique than the others. In vitro evaluation showed statistically significant differences between the control group and other flowable composites (groups 2, 3, and 4), and our findings were not in accordance with findings of Frankenberger et al.[28] Flowable composites are produced mainly for use on etched dentin surfaces. We believe that the manufacturer's recommendation for no primer use on etched enamel surface with Flows-Rite composite makes it unsuitable for bracket bonding. This flowable composite should not be used to replace bonding agents and is not advocated because of the significantly lower SBS values achieved.

The ARI developed by Artun and Bergland[29] has been used by many investigators to help standardize bond failure analysis. The ARI may oversimplify the very complex issues of bond failure analysis, but it does allow for statistical analysis and cross-study comparisons. A review of the literature reveals that although many investigators use an ARI system, they often modify the criteria,[30] the number system,[10,31–34] or both for their project. For the present study, the ARI scores follow the comprehensive criteria used by Bishara et al.[6,10,31–34]

Many investigators indicated in SBS studies that metal brackets failed predominantly at the bracket-adhesive interface.[11,35,36] When the three flowable composites and one orthodontic adhesive were applied on the etched enamel surface, the failure rate increased and the site of bond failure, statistically significant, shifted toward the bracket-adhesive interface (ARI scores of 1 or 2). The distributions of the ARI scores are shown in Table 3. These findings revealed that the flowable composites did not bond to the bracket base as effectively as did the control group.

Most of the failures of the flowable composites were at the bracket-adhesive interface, but the enamel-adhesive interface was fine. It was believed that possibly a different bracket base may adhere better, or the use of a composite custom base as used in indirect bonding may overcome this weak point. If so, this would make flowable composites unsuitable for direct bonding but possibly suitable for indirect bonding.

CONCLUSIONS

In this study, three restorative flowable composites were compared with a conventional orthodontic adhesive (Transbond XT) for in vitro SBS and location of the adhesive failure.

An orthodontic composite resin (Transbond XT) displayed significantly greater SBS values than the other flowable composites (Transbond XT > Flows-Rite = Flow Line = Flow), although the bond strengths for all four composites were clinically acceptable. However, the minimum SBS values of these flowable composites are very low. Clinical conditions may significantly differ from an in vitro setting. Moreover, heat and humidity conditions of the oral cavity are highly variable. Because of the probable differences in in vivo and in vitro conditions, it is not suggested that flowable composites can be applied for orthodontic use.

There were no significant differences in the mean SBS among flowable composites (Flows-Rite, Pulpdent; Flow Line, Heraeus Kulzer; and Filtek Flow, 3M).

Except for the control group (Transbond XT), all the flowable composites tended to display adhesive failure at the bracket-adhesive interface (ARI scores 1 and 2).

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