

## Are Flowable Resin-Based Composites a Reliable Material for Metal Orthodontic Bracket Bonding?

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### Abstract

**Aim:** To compare the tensile bond strength (TBS) and adhesive remnant index (ARI) of three flowable resin-based composites and three orthodontic adhesive systems for metal bracket bonding.

**Methods and Materials:** Sixty bovine incisors were randomly divided into six groups. Enamel surfaces were etched with 37 percent phosphoric acid for 30 seconds and stainless steel orthodontic brackets were bonded using either flowable resin-based composites (3M Flow, FL; Tetric Flow, TF; and Wave, WA) or orthodontic bonding systems (Transbond XT, TX; Concise Orthodontic, CO; Fill Magic Ortodôntico, FM). All specimens were thermal cycled and stored in distilled water at 37°C for 24 hours, after which they were subsequently tested for TBS using a universal testing machine. ARI scores were determined after the failure of brackets. TBS and ARI data were submitted to ANOVA, Tukey, and Kruskal-Wallis tests ( $p=0.05$ ), respectively.

**Results:** Rankings of the resin-based composites based on TBS means (MPa) were TX ( $6.4\pm 2.1$ ), followed by CO ( $4.5\pm 2.7$ ), FM ( $3.7\pm 1.2$ ), FL ( $3.6\pm 1.2$ ), TF ( $3.3\pm 1.2$ ), and WA ( $2.4\pm 0.6$ ). CO exhibited the lowest ARI mean score ( $0.9\pm 1.2$ ) which was significantly different from the other five materials: TX ( $2.8\pm 0.42$ ), FM ( $2.8\pm 0.42$ ), FL ( $2.9\pm 0.32$ ), TF ( $2.9\pm 0.32$ ), and WA ( $3.0\pm 0.01$ ). However, there were no statistically significant differences among the other groups with mean scores of 2.8–3.0. A score of 3.0 indicated that all the resin remained bonded to the tooth surface.



**Conclusions:** The flowable resin-based composites tested (FI, TF, and WA) used to bond metal orthodontic brackets to bovine enamel had low mean TBS values but acceptable ARI mean scores.

**Clinical Significance:** Flowable composites may not be appropriate for bracket bonding, unless the teeth to be bonded are not subjected to higher orthodontic stresses, such as those without an antagonist.

**Keywords:** Laboratory research, flowable composites, orthodontic bracket bonding, resin-based composites, tensile bond strength.

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## Introduction

Bonding orthodontic brackets to etched enamel has been used for over 50 years, and over this time period several improvements have been made in materials and techniques. Metal primers have been developed, along with new orthodontic brackets, such as adhesive precoated brackets, and new bonding materials. In spite of these advances, bracket rebonding is a frequent and undesirable problem in orthodontics that may delay treatment completion and increase time and material costs. In the oral cavity, bonded brackets are subjected to a combination of tensile, shear, and torsional loads.<sup>1</sup> Moreover, environmental factors such as saliva, chemical and physical degradation, as well as erosion by food and bacterial activity also can be responsible for the deterioration of the bonding interface over time.<sup>2</sup> Undesirable bracket failure rates of between 10 and 32 percent were reported when these brackets were bonded using light-cured adhesive paste and resin-modified glass ionomer cement, respectively.<sup>3,4</sup>

Obtaining a successfully long-term bonded bracket depends, among other factors, on achieving a stable interface of the bonding material with the bracket itself and with the tooth structure.<sup>5</sup> These interfaces must be strong enough to support the contraction of the adhesive/cement, normal oral functions, and forces generated by the orthodontic movement,<sup>6</sup> often cited as approximately 6 to 8 MPa. Yet successful clinical bonding has been reported with an adhesive giving an *in vitro* tensile bond strength of 5 MPa.<sup>7</sup> However the bonding strength must not exceed 10 MPa; otherwise the tensile strength of the enamel may be exceeded, leading to enamel chipping and crack formation.<sup>8</sup>

A variety of bonding materials are available to attach brackets to teeth in orthodontics. The most well known are the adhesive resins, which consist of an organic matrix with inorganic fillers. One system can be chemically cured via



a catalyst-base reaction while the other system relies on activation from a visible light source. The first system consists of two pastes that must be dispensed in equal parts and mechanically mixed until a homogeneous material is achieved. However, with this particular approach it is difficult to reproduce the same viscosity with each mix. This technique also can result in the inclusion of air bubbles into the mixed paste, which are then responsible for preventing complete polymerization and reducing the strength of the set cement.

On the other hand, light-activated adhesive resins are provided ready-to-use, which reduces variations in viscosity and other mechanical properties between bonding procedures or even batches. These resins offer clinicians better control of setting time. Capitalizing on these characteristics, light-activated resins appear to be an interesting alternative to attach orthodontic devices to tooth structure. Their main disadvantage remains the high cost of these materials.

Flowable composite resin was developed in the 1990s to provide an easy handling material with reduced viscosity produced by using smaller filler sizes and less volume of filler than conventional hybrid resin-based composites.<sup>9,10</sup> A low viscosity allows these products to be used for a number of clinical applications. A loading syringe tip, for example, facilitates good material penetration in difficult access areas.<sup>9</sup> Flowable resin also can be easily spread over a surface, has a good penetration power, can be light activated, and is commercially available at affordable prices. However, it remains to be seen if flowable composite resin is as reliable a substitute for conventional bonding of orthodontic brackets.

The aim of this study was to evaluate the bonding characteristics of three flowable composites for orthodontic bracket bonding using a tensile bond strength (TBS) test and an adhesive remnant index (ARI) assessment. These results were then compared with three orthodontic adhesive systems. The hypothesis tested was that the flowable composites are equally as effective as orthodontic adhesive materials for bonding orthodontic brackets.

## Methods and Materials

Sixty sound bovine mandibular central incisors were selected, cleaned, and randomly divided in six groups (n=10, Table 1), then stored in 2 percent chloramine T solution at 5°C.

The teeth were placed on an adhesive tape lingual side down and embedded in plastic cylinders filled with autopolymerizing poly (methyl methacrylate) resin (Jet, Clássico Produtos

Odontológicos, São Paulo, Brazil). The facial enamel surface was polished using a motorized polishing wheel and pads of declining grit size (220, 320, 400, 600), etched with 37% phosphoric acid for 30 seconds (Total Etch, Ivoclar Vivadent Inc. Liechtenstein), rinsed with tap water for 1 minute and dried with compressed air for 10 seconds. One metal edgewise orthodontic bracket for mandibular central incisors (slot dimensions 0.46 x 0.76 mm, Dental Morelli, Sorocaba, Brazil) was bonded to each tooth according to the respective bonding protocol listed in Table 1 for each material. During the setting reaction, brackets were kept in position using a Gilmore needle (453 g) for 1 minute. Except for the CO and FM groups, light polymerization at the mesial and distal margin was performed using a visible light-curing unit (XL 2500 3M-ESPE, St. Paul, MN, USA) for the amount of time indicated in Table 1 for groups FL, TF, TX, and WA.

Prior to the tensile bonding strength (TBS) test, the bonding interface was stressed by thermocycling

**Table 1. Bonding protocol of each orthodontic bonding system (TX, CO, and FM) and flowable composite (FL, TF, and WA) tested.**

Group	Bonding Protocol
TX (Unitek Transbond XT, 3M Unitek, Monrovia, CA, USA) (light-activated product)	<ul style="list-style-type: none"> <li>• Apply primer on the enamel surface; leave undisturbed for 20 seconds.</li> <li>• Apply a gentle burst of air for 1–2 seconds.</li> <li>• Apply a small amount of adhesive paste onto bracket base, which is then positioned on the tooth, pressed firmly into place, and light polymerized for 20 seconds.</li> </ul>
CO (3M Unitek Concise Orthodontic, 3M Center, St. Paul, MN, USA) (chemically activated product)	<ul style="list-style-type: none"> <li>• Dispense equal portions of both A and B paste and mix thoroughly for 10 seconds.</li> <li>• Apply a thin coat of the mixed resins to the etched enamel surface.</li> <li>• Prepare a second batch of resin paste by mixing equal portions of both pastes for 20 seconds.</li> <li>• Apply the mixed pastes to the bracket base, place it in position, and hold for 1 minute to polymerize.</li> </ul>
FM (Fill Magic Ortodôntico, Vigodent, Rio de Janeiro, Brazil) (chemically activated product)	<ul style="list-style-type: none"> <li>• Apply a thin layer of the fluoride-releasing adhesive paste over the bracket base and place it in position; hold for 1 minute until polymerized.</li> </ul>
FL (3M Flow 3M Center, St. Paul, MN, USA) (light-activated product)	<ul style="list-style-type: none"> <li>• Apply the primer (3M Single Bond Adhesive) to the etched surface in a thin film and light polymerize for 10 seconds.</li> <li>• Cover the bracket surface with FL flowable composite, place it in position, and light polymerize for 20 seconds.</li> </ul>
TF (Tetric Flow, Ivoclar-Vivadent, Schaan, Liechtenstein)	<ul style="list-style-type: none"> <li>• Apply a thin layer of primer (Excite, Ivoclar-Vivadent) on the etched enamel, followed by a layer of flowable resin;</li> <li>• Apply TF resin to completely cover the bracket and then then light polymerize it for 40 seconds.</li> </ul>
WA (Wave, SDI, Bayswater, Australia) (light-activated product)	<ul style="list-style-type: none"> <li>• Spread a thin layer of single component adhesive (Stae, SDI) over the enamel surface, then light polymerize for 10 seconds;</li> <li>• Apply a layer of the microhybrid composite of low viscosity WA into the bracket, place in position, and light polymerize for 40 seconds.</li> </ul>

the specimens for 700 cycles alternating between water baths of 5°C and 55°C with a dwell time of 60 seconds in each bath and a transfer time of 10 seconds. After storage in distilled water at 37°C for 24 hours, the specimens were tested for TBS using a universal testing machine (Kratos Dynamômetros, São Paulo, Brazil) with a crosshead speed of 0.5 mm/min. Once debonded, each specimen was examined under a stereoscopic microscope at 90X magnification to identify the location of the bond failure. The residual composite remaining on each tooth was measured using an adhesive remnant index (ARI) where each specimen was scored according to the amount of adhesive (or composite resin) remaining on the enamel surface as follows: 0=no adhesive remaining, 1=less than 50 percent of the adhesive remaining, 2=more than 50 percent of the adhesive remaining, 3=all the adhesive remained bonded to the etched enamel surface.

The TBS data were subjected to ANOVA and Tukey tests, while ARI data were analyzed by a Kruskal-Wallis test ( $p=0.05$ ) in which the groups were compared based on a specimen rank mean.

## Results

### Tensile Bond Strength (TBS)

ANOVA of TBS data showed that the influence of the composite materials was statistically significant ( $p<0.01$ , Figure 1). The TX group had the highest TBS mean ( $6.4\pm 2.1$  MPa); however, it was not statistically different from CO ( $4.5\pm 2.7$  MPa). There was no statistical difference among

groups CO, FM ( $3.7\pm 1.2$  MPa), MF ( $3.6\pm 1.2$  MPa), TF ( $3.3\pm 1.2$  MPa), and WA ( $2.4\pm 0.6$  MPa).

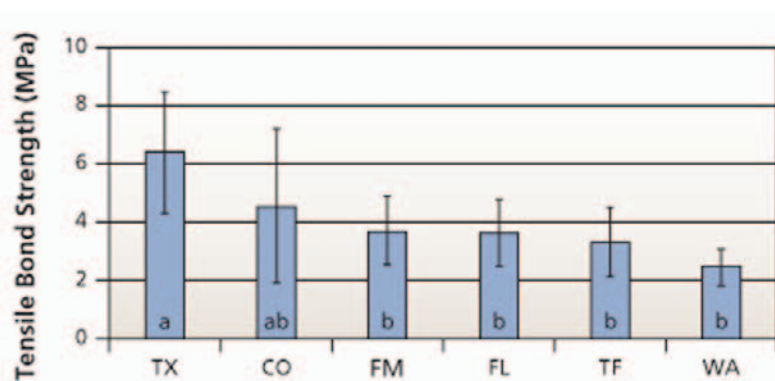
### Adhesive Remnant Index (ARI)

According to the Kruskal-Wallis analysis and based on the mean ARI values, there was a statistical difference among the composite materials ( $p<0.001$ ) with CO having the lowest ARI mean and median values compared to the other resins. However, there was no statistical difference among the other five products tested (Table 2).

## Discussion

In clinical practice, a bonding technique should provide strong bonds to enamel and the bracket surface itself to prevent premature bracket loss. The debonding of brackets can lead to additional enamel loss due to the need for an additional acid-etching procedure and increase the treatment time.<sup>1</sup> Clinically, the minimum bond strength required for an adhesive material to attach a bracket is difficult to determine because occlusal loads vary considerably and an assessment of the force transmitted to an individual tooth is difficult to obtain. For these reasons, opinions vary as to the actual bond strength necessary for an ideal bracket bonding material.<sup>5,11,12</sup>

In the present study, 5 MPa was established as the minimal TBS value for brackets bonding because successful bracket bonding had been reported with this TBS value.<sup>13</sup> Since all the flowable composites tested presented TBS means at least 30 percent lower than this reference value, the



**Figure 1.** Tensile bond strength (MPa) of the orthodontic bonding systems (TX, CO, and FM) and flowable resin-based composites (MF, TF, and WA). Same letters indicate no statistical difference among the groups according to the Tukey test at  $p=0.05$ .



**Table 2. ARI scores for residual adhesive on the enamel surface of each material tested (n=10)\***

Groups	0	1	2	3	Mean of Scores**	Standard Deviation	Median Value
TX	0	0	2	8	2.8 <sup>a</sup>	0.42	3
CO	6	0	3	1	0.9 <sup>b</sup>	1.20	0
FM	0	0	2	8	2.8 <sup>a</sup>	0.42	3
FL	0	0	1	9	2.9 <sup>a</sup>	0.32	3
TF	0	0	1	9	2.9 <sup>a</sup>	0.32	3
WA	0	0	0	10	3.0 <sup>a</sup>	0.01	3

\*ARI scores: 0=no adhesive left on tooth surface, 1=less than 50% of adhesive left on tooth surface, 2=more than 50% of adhesive left on tooth surface, 3=all adhesive left on tooth surface.  
 \*\*Same superscript letter indicates no significant difference among the groups according to the Kruskal-Wallis test at p<0.05.

hypothesis of this study was rejected. In addition, one of the materials exclusively developed for orthodontic procedures (FM) presented a lower TBS mean than 5 MPa, which may compromise its clinical performance. The present results are in agreement with a previous study that used shear bond strength (SBS) to evaluate the performance of flowable resin to bonding brackets. The authors concluded that flowable composites are not indicated for bracket bonding because their SBS was approximately 50 percent lower than that obtained for Transbond XT (17.1 MPa).<sup>14</sup> However, another study found differences between the results of flowable composites (7.2 to 8.3 MPa), without using an intermediate bonding resin, and Transbond XT (10.9 MPa). The authors concluded that the SBS values of flowable composites were sufficient for orthodontic needs.<sup>8</sup>

Several explanations are possible for those controversial conclusions. First has to do with the methodology applied. In the present study tensile bond strength was used, while others evaluated shear bond strength. The limitations of the SBS techniques to measure the quality of adhesive interfaces are well known.<sup>11,15-18</sup> One study concluded that sheer bond strength technique was not appropriate to evaluate the adhesive interface between composite resin and ceramic.<sup>15</sup> This interface is influenced by the cohesive strength of the base material used rather than the bond strength of the adhesive.<sup>15</sup> The authors concluded that the TBS gives a more credible outcome when evaluating the bond strength of resin composite to ceramic.<sup>15</sup> They also showed that SBS may produce similar bond strength results from different

conditions depending on only the geometry of the SBS test arrangement. These reasons seem to be sufficient to justify the selection of a TBS test in the present study. They too may help to explain why the previous study reported similar SBS values for both types of materials, accepting the use of flowable composites for attaching brackets while others have not.<sup>19</sup>

Second, in the present study, the specimens were thermal cycled, which also may have reduced the TBS values. Thermal cycling is intended to simulate what happens to the bond strength *in vivo* compared to plain water storage.<sup>11</sup> It is well known degradation of the bonding interfaces occurs over time,<sup>12</sup> so the TBS values obtained after storage for 24 hours show an optimal snapshot that hardly fits with the long-term clinical situation to which orthodontic brackets will be exposed. On the other hand, thermal cycling stresses the bonding interface and provides a better perspective of how weakened the interface can be in a clinical situation. Finally, the adhesion substrate used in the present study was bovine enamel, while in other studies human enamel was used. Even though it has been shown that the use of bovine enamel is a trustworthy substitute for human enamel in bonding studies,<sup>20,21</sup> the mean bond values from a bovine substrate are always slightly lower than those obtained from human enamel.<sup>22</sup>

Although TX and CO were statistically similar in their TBS, the latter product had the highest variability. CO is a chemically activated product, which guarantees its high degree of polymerization in total or partial absence of a curing light.

However, the need to mechanically mix the base and catalyst pastes together may lead to air entrapment and void. Any resulting voids at the adhesive interface can adversely affect the bond and increase the range of TBS values.<sup>23</sup> Moreover, CO had the lowest mean ARI score. An ARI mean score of 0 or 1 indicates that the fracture occurred at the enamel–adhesive interface and that outcome increases the possibility of enamel fractures and damage during bracket debonding.<sup>16</sup>

An ARI score of 3 represents a bonding failure at the bracket–adhesive interface but is likely to result in a low incidence of enamel fractures.<sup>24</sup> Therefore, a bond failure at the bracket–adhesive interface would be more desirable to minimize damage to the tooth surface (enamel fractures).<sup>8</sup> In this study most of the materials had a median ARI score of 3, which indicates that the composite penetrated sufficiently into the retentive pores on the enamel surface but not into the metal bracket base.<sup>14</sup> Several TBS and SBS studies have shown that metal brackets fail predominantly at the bracket–adhesive interface.<sup>17,18,25,26</sup>

## Conclusion

In spite of the fact that flowable composites presented acceptable ARI scores, their TBS mean values were lower than the required bond strength for bracket bonding. Therefore, within the limits of this study, it was concluded that the flowable composites may not be satisfactory alternative materials for orthodontic bracket bonding.

## Clinical Significance

Flowable composites may not be appropriate for bracket bonding unless the teeth to be bonded are not subjected to higher orthodontic stresses, such as those without an antagonist.

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