Original Article

Effect of Using a New Cyanoacrylate Adhesive on the Shear Bond Strength of Orthodontic Brackets

Samir E. Bishara, BDS, MS, DDS, D Ortho[a]; Leigh VonWald, BS[b]; John F. Laffoon, BS[c]; John J. Warren, MS, DDS[d]

Abstract: During bonding of orthodontic brackets to enamel, conventional adhesive systems use three different agents: an enamel conditioner, a primer solution, and an adhesive resin. A unique characteristic of some new bonding systems is that they need neither a priming agent nor a curing light to bond brackets. Such an approach should be more cost-effective for the clinician and indirectly also for the patient. The purpose of this study was to determine the effects of using a cyanoacrylate adhesive on the shear bond strength of orthodontic brackets and on the bracket/adhesive failure mode. The brackets were bonded to extracted human teeth according to one of two protocols. Group 1: Teeth were etched with 37% phosphoric acid. After applying the primer, the brackets were bonded with Transbond XT (3M Unitek, Monrovia, Calif) and were light-cured for 20 seconds. Group 2: Teeth were etched with 35% phosphoric acid. The brackets were then bonded with Smartbond (Gestenco International, Göthenburg, Sweden). The present in vitro findings indicated that the use of the cyanoacrylate adhesive to bond orthodontic brackets to the enamel surface did not result in a significantly different ($P = .24$) shear bond force (mean $= 5.8 \pm 2.4$ MPa) as compared to the control group (mean $= 5.2 \pm 2.9$ MPa). The comparison of the Adhesive Remnant Index scores indicated that there was significantly ($P = .006$) less residual adhesive remaining on the tooth with the cyanoacrylate than on the tooth with the conventional adhesive system. In conclusion, the new adhesive has the potential to be used to bond orthodontic brackets while reducing the total bonding time. (*Angle Orthod* 2001;71:466–469.)

Key Words: Adhesive; Cyanoacrylate; Shear bond strength; Orthodontic brackets

INTRODUCTION

In the process of bonding orthodontic brackets to enamel, conventional adhesive systems use three different agents: an enamel conditioner, a primer solution, and an adhesive resin. A unique characteristic of some new bonding systems in operative dentistry is that these systems combine the conditioning and priming agents into a single acidic primer solution for simultaneous use on both enamel and dentin.[1,2]

These relatively new systems were used originally on dentin.[1,3] Essentially, the acidic part of the primer dissolves the smear layer and incorporates it into the mixture. Acidic primer solutions also demineralize the dentin and encapsulate the collagen fibers and hydroxyapatite crystals.[2] This simultaneous conditioning and priming allows penetration of the monomer into the dentin. The adhesive resin component will then diffuse into the primed dentin, producing a ‘‘hybrid layer.’’[3] These new systems were also found to be effective when bonding to enamel.[4]

In the early 1990s, maleic acid was introduced as an alternative etching material in an attempt to control the depth of the enamel etch. Barkmeier et al[5] compared the use of 10% maleic acid to 37% phosphoric acid and reported that the resulting bond strengths were essentially similar. Scanning electron microscopy of enamel surfaces treated with 10% maleic acid and 37% phosphoric acid revealed similar morphologic patterns, but the depth of the etched surface was significantly less with maleic acid.[6]

Orthodontists utilize the acid-etch bonding technique as a means of attaching brackets to the enamel surface. Maintaining a sound, unblemished enamel surface after debonding orthodontic brackets is a primary concern to the clinician. As a result, bond failure at the bracket-adhesive interface or within the adhesive is more desirable (safer) than

[a] Professor, Orthodontic Department, College of Dentistry, University of Iowa, Iowa City, Iowa.

[b] Research Assistant, College of Dentistry, University of Iowa, Iowa City, Iowa.

[c] Research Assistant, College of Dentistry, University of Iowa, Iowa City, Iowa.

[d] Assistant Professor, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, Iowa City, Iowa.

Corresponding author: Dr Samir E. Bishara, Orthodontic Department, College of Dentistry, University of Iowa, Iowa City, IA 52242 (e-mail: karla-starckovich@uiowa.edu).

Accepted: May 2001. Submitted: January 2001.

bond failure at the adhesive-enamel interface, because enamel fracture and crazing have been reported at the time of bracket debonding, especially with ceramic brackets.[7] As a result, maleic acid and acidic primers that contain Phenyl P have also been tested and have been found to attain an adequate orthodontic bracket bond strength after 24 hours without increasing the depth of enamel dissolution.[8]

Combining conditioning and priming into a single treatment step or eliminating the need for one of these two components can potentially result in improvements in both time and cost-effectiveness for both the clinician and, indirectly, the patient. One such material contains methacrylated phosphoric acid esters that combine the acidic component for conditioning the enamel with the primer. This material has been used with orthodontic composite adhesives and has been found to have a clinically acceptable shear bond strength.[9]

More recently, a new adhesive has been introduced that does not require the use of a primer or the use of a curing light during bonding. In a recent study, Örtendahl and Örtengren[10] compared the bond strength of a cyanoacrylate adhesive with eight other adhesives. They found that after 24 hours, the new adhesive performed as well as or better than the composite resins used for bonding both metal and plastic brackets. From a clinical perspective, it is important to test these new adhesives within the first half hour after bonding, when the initial arch wires are ligated.

The purposes of this study were (1) to determine the effects of using a newly introduced 1-step cyanoacrylate adhesive on the shear bond strength of orthodontic brackets within the first half hour after bonding, and (2) to determine the bracket/adhesive failure mode.

MATERIALS AND METHODS

Teeth

Forty freshly extracted human molars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included: (1) intact buccal enamel, (2) tooth not subjected to any pretreatment chemical agents such as hydrogen peroxide, (3) no cracks caused by the extraction forceps, and (4) no caries. The teeth were cleansed and then polished with pumice and rubber prophylactic cups for 10 seconds.

Brackets Used

Orthodontic metal brackets (Victory Series; 3M Unitek, Monrovia, Calif) were used in this study. The average bracket base surface area was determined to be 12.2 mm^2.

Bonding Procedure

The teeth were randomly divided into two groups. The brackets were bonded to the teeth according to one of two protocols:

Group 1—Bonding with Transbond XT (3M Unitek): Twenty teeth were etched with 37% phosphoric acid gel for 30 seconds. The teeth were thoroughly washed for 20 seconds and air dried. The sealant was applied, and the brackets were then bonded and light cured for 20 seconds following the manufacturer's instructions.

Group 2—Bonding with Smartbond (Gestenco International, Göthenburg, Sweden): The Smartbond adhesive contains ethyl-cyanoacrylate. The bonding procedure followed the manufacturer's instructions. Twenty teeth were cleaned and polished. A 35% phosphoric acid etch was applied for 10 seconds, and the teeth were washed thoroughly for 20 seconds and air dried. A moist cotton roll was used to wet the enamel surface before the adhesive was applied.

The manufacturer recommends two methods of applying the adhesive to the bracket base, ie, either directly from the syringe containing the adhesive or using a microbrush. In the present experiment the brush method was used because it allowed for the controlled application of a uniform thickness of the adhesive on the bracket base.

Each bracket was subjected to a compressive force of $300 \times g$ using a force gauge (Correx Co, Bern, Switzerland) for 10 seconds, following which excess bonding resin was removed using a sharp scaler.

It is interesting to note that, until the cyanoacrylate adhesive is placed on the wet enamel surface, the adhesive will not readily set. Once the adhesive comes into contact with the wet enamel surface, the clinician has 3–5 seconds to adjust the placement of the bracket before the adhesive starts to set. According to the manufacturer, the adhesive will be sufficiently set within 3–5 minutes, at which time the initial arch wires can be ligated. To be more specific, according to the manufacturer, the adhesive attains 70% of its ultimate bond strength within 10 minutes, 80% within 1 hour, and full strength within 12 hours.

Debonding Procedure

The teeth were embedded in acrylic in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surface of the tooth perpendicular to the bottom of the mold. Each tooth was oriented with the testing device as a guide, so its labial surface was parallel to the force during the shear strength test. A steel rod with one flattened end was attached to the crosshead of a Zwick test machine (Zwick Gm bH & Co, Ulm, Germany). An occlusogingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. A computer,

TABLE 1. Descriptive Statistics and Results of Student's *t*-test Comparing the Shear Bond Strengths in Megapascals (MPa) of the 2 Groups Evaluated

Groups Tested[a]	Mean	SD	Range
Acid + primer + composite (Transbond)	5.2	2.9	1.1–10.4
Acid + cyanoacrylate (Smartbond)	5.8	2.4	2.1–11.1

[a] *t* value = 0.71; $P = .24$.

TABLE 2. Frequency Distribution and the Results of the χ^2 Analysis of the Adhesive Remnant Index (ARI) of the 2 Groups Evaluated

	ARI Scores[b]				
Groups Tested[a]	1	2	3	4	5
Acid + primer + composite (Transbond)	—	15	5	—	—
Acid + cyanoacrylate (Smartbond)	—	2	12	6	—

[a] $\chi^2 = 19.76$; $P = .001$.
[b] 1 indicates all composite on tooth; 2, >90% of composite on tooth; 3, >10% but <90% of composite on tooth; 4, <10% composite on tooth; and 5, no composite on tooth.

electronically connected with the Zwick test machine, recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 5 mm/min within 30 minutes after bonding.

Residual Adhesive

After debonding, the teeth and brackets were examined under 10× magnification. Any adhesive remaining after bracket removal was assessed according to the Adhesive Remnant Index (ARI) and scored with respect to the amount of resin material adhering to the enamel surface.[11] The ARI scale has a range between 5 and 1, with 5 indicating that no composite remained on the enamel; 4, that less than 10% of composite remained on the tooth surface; 3, that more than 10% but less than 90% of the composite remained on the tooth; 2, that more than 90% of the composite remained; and 1, that all of the composite remained on the tooth, as well as the impression of the bracket base. The ARI scores were also used as a more comprehensive method of defining the site of bond failure between the enamel, the adhesive, and the bracket base.

Statistical Analysis

Descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated for each of the two test groups.

Student's *t*-test was used to determine if significant differences were present in the bond strength between the two groups. The χ^2 test was also used to determine significant differences in the ARI scores between the groups. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Shear Bond Strength Comparisons

The descriptive statistics for the shear bond strengths of the two groups are presented in Table 1. The results of the Student's *t*-test indicated that there were no significant differences in the shear bond strength of the cyanoacrylate adhesive when compared to the conventional adhesive system that requires both phosphoric acid and primer before light curing.

ARI Comparisons

For the ARI comparisons (see Table 2), the results of the χ^2 comparisons indicated that there was a significant difference ($P = .001$) between the group bonded with the cyanoacrylate as compared to the composite group. With the use of the cyanoacrylate there was a higher frequency of ARI scores of 3, indicating a more cohesive failure mode; ie, there were various amounts of adhesive remaining on the tooth (Table 2), but less than with the composite.

DISCUSSION

The direct bonding of orthodontic brackets has revolutionized and improved the clinical practice of orthodontics. However, there is a need to improve on the bonding procedure by saving time and also minimizing enamel loss during bonding and debonding without jeopardizing the ability to maintain a clinically useful bond strength. Traditionally, the use of acid etchants followed by a primer was an essential part of the bonding procedure of composite adhesives in order to allow good wetting and penetration of the sealant into the enamel surface.[6] The use of the new self-etching primers for orthodontic purposes was thought to simplify the clinical handling of adhesive systems by combining the etchant and the primer in one application.[1,3,8] The earlier generation of acidic primers was selectively compatible with different adhesives, and as a result, they either produced significantly lower bond strength or needed significantly more working time.[8] On the other hand, the newer generation of self-etch primers is compatible with composite adhesives and has adequate bond strength.[9]

The present study evaluated the performance of a new cyanoacrylate adhesive that does not need any primer at all and compared it to a conventional 3-step composite adhesive. From a clinical perspective, Smartbond can be considered a 1-step orthodontic adhesive, because it does not need the application of a layer of sealant, although it does need a wet enamel surface. Furthermore, it does not need to be mixed with another component to be activated, nor does it need to be light cured in order to obtain an effective bond. On the other hand, when using this adhesive, it is necessary that it come in contact with water on the enamel surface in order for the uncured monomer to be activated and to polymerize. The presence of water in close proximity to a thin layer of adhesive will ensure that most of the monomer will be activated and converted into the more stable and cured polymer within a short period of time. Therefore, it is very important to follow the manufacturer's instruction literally and to apply a thin layer of the adhesive to ensure a quick and uniform setting.

In the present study, during debonding, the adhesive thickness on a few teeth was found to be thicker than optimal. In these cases, it was observed that the center part of the adhesive was still soft (sticky). It was also interesting to note that although the cyanoacrylate under the bracket sufficiently hardened within 3–5 minutes, the unused adhesive left sitting on a pad at room temperature did not harden for at least 15 minutes. As explained earlier, the material needs to be in contact with a wet surface for it to set; ie, it is moisture activated.

One advantage of the cyanoacrylate adhesive is that it readily adheres to composite and porcelain surfaces, a property that has not been tested in this study. Furthermore, according to the manufacturer, excess adhesive around the brackets does not need to be removed mechanically at the time of bonding, because it will polymerize instantly after being sprayed with water and should turn into a white powder that will be brushed off by the patient. Again, this advantage has not been evaluated in this study.

The present findings indicated that the use of a cyanoacrylate adhesive to bond orthodontic brackets to the enamel surface provided the clinically acceptable bond force levels suggested by Reynolds.[12] However, it needs to be remembered that this is an in vitro study, and care should be taken in extrapolating the results to those that might be obtained in the oral environment.

CONCLUSION

By reducing the number of steps during bonding, clinicians are able to save time as well as reduce the potential for error through contamination during the bonding procedure. The present results indicated that the newly introduced cyanoacrylate adhesive has adequate shear bond strength in the first half hour after bonding and does not require the use of a primer or a curing light. Therefore, this adhesive has the potential to be successfully used in the bonding of orthodontic brackets.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Dr Erik Larsson and Dr Ulf Adolfsson for their help with this study.

REFERENCES

1. Chigira H, Koike T, Hasegawa T, Itoh K, Wakumoto S, Hyakawa T. Effect of the self etching dentin primers on the bonding efficacy of dentine adhesive. *Dent Mater J.* 1989;8:86–92.
2. Nishida K, Yamauchi J, Wada T, Hosoda H. Development of a new bonding system [Abstract 267]. *J Dent Res.* 1993;72:137–.
3. Nakabayashi N. Dentinal bonding mechanisms. *Quint Int.* 1991; 22:73–74.
4. Gordan VV. *Acidic Primers in Dentin and Enamel—Shear Bond Strength and Microleakage* [master's thesis]. Iowa City, Iowa: University of Iowa; 1997.
5. Barkmeier WW, Erickson RL. Shear bond strength of composite to enamel and dentin using Scotchbond multi-purpose. *Am J Dent.* 1994;7:175–179.
6. Triolo PT Jr, Swift EJ Jr, Mudgil A, Levine A. Effects of etching time on enamel bond strengths. *Am J Dent.* 1993;6:302–304.
7. Britton JC, McInnes P, Weinberg R, Ledoux WR, Retief DH. Shear bond strength of ceramic orthodontic brackets to enamel. *Am J Orthod Dentofac Orthop.* 1990;98:348–353.
8. Bishara SE, Gordan VV, VonWald L, Olson ME. Effect of an acidic primer on shear bond strength of orthodontic brackets. *Am J Orthod Dentofac Orthop.* 1998;114:243–247.
9. Bishara SE, VonWald L, Laffoon JF, Warren JJ. Effect of using a self-etched primer/adhesive on the shear bond strength of orthodontic brackets. *Am J Orthod Dentofac Orthop.* 2001; 119: 621–624.
10. Örtendahl TW, Örtengren U. A new orthodontic bonding adhesive. *J Clin Orthod.* 2000;34:50–54.
11. Bishara SE, VonWald L, Olsen ME, Laffoon JF, Jakobsen JR. Effect of time on the shear bond strength of glass ionomer and composite orthodontic adhesives. *Am J Orthod Dentofac Orthop.* 1999;116:616–620.
12. Reynolds IR. A review of direct orthodontic bonding. *Br J Orthod.* 1979;2:171–178.