ORIGINAL ARTICLE

Bond failure and decalcification: A comparison of a cyanoacrylate and a composite resin bonding system in vivo

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This prospective, in vivo study compared bond failure and enamel decalcification with a cyanoacrylate bracket bonding system (SmartBond, Gestenco International, Gothenburg, Sweden) and a traditional light-cured composite system (Light Bond, Reliance Orthodontic Products, Itasca, Ill). A total of 327 teeth were evaluated after a period of 12 to 14 months; 163 experimental teeth were bonded with the cyanoacrylate bonding system, and 164 control teeth were bonded with the light-cured composite resin. All teeth were evaluated for breakage (bond failure). The average percentage of bracket failures with cyanoacrylate was 55.6% compared with 11.3% with composite resin ($P < .001$). All maxillary anterior teeth (94) were evaluated for enamel decalcification on a graded scale. Occurrence of enamel decalcification between the 2 bonding systems after 1 year of orthodontic treatment was similar. The cyanoacrylate bonding material had more than 4 times as many bond failures and a similar amount of decalcification as the traditional composite material. Cyanoacrylate as a routine orthodontic bonding agent is not a suitable bonding material for clinical practice at this time. It is important to test new bonding systems in vivo in several studies before using them in routine clinical practice. (Am J Orthod Dentofacial Orthop 2003;123:624-7)

Efficiency in the orthodontic bracket bonding procedure might be a goal in an average orthodontic office. For light-curing composite systems, there has been a move toward quicker curing time with more intense curing units. For self-curing bonding systems, a reasonable self-curing time might be one of the apparent goals.

A cyanoacrylate (SmartBond, Gestenco International, Gothenburg, Sweden) has been introduced as a self-curing orthodontic bonding system. It was approved by the U. S. Food and Drug Administration for orthodontic use in 1999. This bonding system eliminated the application of primer and the light-curing steps, in addition to reducing etching time to 10 seconds. Water acts as an activator for the polymerization reaction.

Recent in vitro studies by Bishara et al[1] of the shear bond strength of cyanoacrylate concluded that bonding brackets with cyanoacrylate did not result in a significantly different shear bond force compared with composite. Örtendahl and Örtengren,[2] in their in vitro study of 24-hour bond strength, concluded that the cyanoacrylate adhesive achieved greater bond strength than the composite that was studied. On the other hand, Al-Munajed et al[3] concluded in their ex vivo (in vitro) study that significantly more bond failures were noted 3 months after bonding with cyanoacrylate.

Enamel decalcification adjacent to orthodontic brackets continues to be a concern. The cyanoacrylate does not purport to release fluoride, whereas fluoride-releasing bonding agents are available that might inhibit decalcification.[4-6]

This prospective, in vivo clinical trial compared bond failure occurrence and enamel decalcification of cyanoacrylate and a traditional light-cured composite resin (Light Bond, Reliance Orthodontic Products, Itasca, Ill).

MATERIAL AND METHODS

The protocol for this study was based on the research model designed by Gaworski et al[7] and Wenderoth et al.[8] The sample comprised 21 patients seeking orthodontic treatment at the Albert Einstein Medical Center's Orthodontic Division in Philadelphia; patients were consecutively selected to participate in the clinical trial. Teeth included in the study were the maxillary and mandibular

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Table I. Bond failure occurrence

Material	Number of teeth	Number of failures	% failures
Cyanoacrylate	163	88	54.0
Composite	164	20	12.2

central incisors, lateral incisors, canines, first premolars, and second premolars. Exclusion criteria were as follows: (1) teeth with porcelain or metal crowns, (2) teeth with composite at the bonding surface, (3) teeth that were not fully erupted, (4) teeth that were scheduled for extraction, and (5) teeth that required repositioning of the brackets early in orthodontic treatment.

Identification of the teeth was based on the universal tooth-numbering system of 1 through 32. The teeth were divided into 2 sets based on odd and even numbers. The even-numbered teeth were bonded with cyanoacrylate, the odd-numbered teeth with light-cured composite resin.

The manufacturer's instructions were followed for each product. This included isolation with cheek and tongue retractors and pumicing of all teeth.

Bond failure occurrence

In the 21 subjects, all teeth that were bonded, including those used for evaluation of decalcification, were used to assess the occurrence of bond failure. Once a tooth was bonded, any bonding failure was recorded, and the tooth was no longer included in the bonding failure study.

Decalcification

Of the 21 patients in the study, 18 were evaluated for enamel decalcification. The remaining 3 patients were not included because they either failed to return for their final decalcification reevaluation visit or did not have the 6 maxillary anterior teeth bonded for the full 12 to 14 months at the time of evaluation. A total of 94 teeth were evaluated: 47 were used as experimental teeth and 47 as the controls.

The 6 maxillary anterior teeth were used to evaluate enamel decalcification. Each tooth was photographed preoperatively and 12 to 14 months later. The Canon Elan IIE 35 mm camera (Canon, Lake Success, NY) with a 100-mm macroscopic lens and Kodak Elitechrome 64 ASA film (Rochester, NY) were used at a 1-to-1 magnification. A predetermined aperture setting at f27 was used with a Canon ring flash.

If there was a bond failure during the clinical trial, the bracket was rebonded with the same material used for that tooth, so that it could be used to evaluate decalcification.

After 12 to 14 months follow-up, brackets and bonding material on the 6 maxillary anterior teeth were removed, and the teeth were photographed with the same protocol as before bonding. Thirty-six sets of slides consisting of both prebonding and follow-up pictures were shown to a team of 10 dental professionals. Each set consisted of 2 to 4 slides that adequately showed each maxillary anterior tooth. The evaluators were not told whether the slides were taken before or after bonding. A standardized rating system was used to evaluate enamel decalcification. Decalcification for each tooth was assessed and ranked as none, slight, or significant. Each tooth was then assigned the median ranks given by the 10 evaluators. By using these median ranks before and after bonding, decalcification was classified as having worsened (or not) 12 to 14 months later.

Statistics

To assess bond failure, the percentage of bracket failures was computed for each material separately for each patient. Then a comparison of the average percentage of bracket failures with the 2 materials was done with a paired *t* test. The difference between those averages and the 95% confidence interval of that difference were computed. Regarding decalcification, statistical analyses were performed with paired comparisons between contralateral pairs and between adjacent pairs. Contralateral comparisons were of the opposite teeth, each receiving a different bonding agent. Adjacent comparisons allowed a regional assessment in the same manner. The McNemar test was used to compare contralateral pairs and also adjacent pairs. All statistical tests were 2-sided. Statistical analyses were performed using SPSS 10.0 (SPSS, Chicago, Ill).

RESULTS

Study group

Of the 21 subjects, 14 were female (age range: 11.7-43.5 years, mean: 17.3) and 7 were male (age range: 12.0-17.4 years, mean: 14.0).

Bond failure occurrence

Of the 163 teeth bonded with cyanoacrylate, 88 (54.0%) had bond failures. Of 164 teeth bonded with the light-cured composite resin, 20 (12.2%) had bond failure (Table I).

The percentage of bracket failures for each material was computed separately for each patient. Among the 21 subjects, the range of bond failure was 11% to 100% for the teeth bonded with cyanoacrylate and 0% to 60% with the composite-bonded teeth. The average percentages of failures were 55.6% with cyanoacrylate and 11.3% with composite resin ($P < .001$) (Table II).

Table II. Bond failure occurrence for each patient

Material	Number of subjects	Range of % failures	Mean % of failures
Cyanoacrylate	21	11-100	55.6
Composite	21	0-60	11.3

Table III. Enamel decalcification

Material	Number of teeth	Mean % of worsened decalcification	SD
Cyanoacrylate	47	78.7	0.290
Composite	47	76.8	0.308

Table IV. Comparison of decalcification—paired teeth

	Sample size		% Unchanged		% With decalcification		Significance
	Cyanoacrylate	Composite	Cyanoacrylate	Composite	Cyanoacrylate	Composite	P
Contralateral teeth							
Central incisors	15	15	20.0	0.0	80.0	100.0	.25
Lateral incisors	18	18	22.2	38.9	77.8	61.1	.38
Canines	12	12	25.0	25.0	75.0	75.0	1.00
Adjacent teeth							
Right canine/lateral	13	13	23.1	46.2	76.9	53.8	.375
Right lateral/central	16	16	18.8	37.5	81.3	62.5	.375
Left central/lateral	15	15	13.3	0.0	86.7	100.0	.500
Left lateral/canine	14	14	28.6	28.6	71.4	71.4	1.000

Decalcification

In determining the occurrence of decalcification, bonding methods were evaluated by examining the teeth before bonding and 12 to 14 months later. Of the maxillary anterior teeth, decalcification worsened in 37 of 47 (78.7%) teeth bonded with cyanoacrylate and in 36 of 47 (76.8%) teeth bonded with composite (Table III).

None of the 7 paired comparisons showed any statistically significant differences in the development of decalcification between cyanoacrylate and composite bonding materials (Tables IV).

DISCUSSION

The average percentages of bracket failures were 55.6% with cyanoacrylate and 11.3% with composite resin. There could be several reasons for the substantially higher bond failure rates with the cyanoacrylate: (1) product deterioration over time, (2) inadequate self-curing time (3 to 5 minutes, according to the manufacturer's instructions), and (3) large gap between bracket and tooth.

The manufacturer's information accompanying the product stated that the excess cyanoacrylate adhesive, after a thin application, does not need to be removed and would eventually be brushed off by the patient; this was observed clinically. This only begs the question of whether the cyanoacrylate between the tooth and bracket is also washed out.

Bishara et al[9] concluded that shear bond strength for cyanoacrylate was greater at 24 hours after orthodontic bonding than at 30 minutes after bonding. Information from the manufacturer indicated that bond strength was a function of time; bond strength was sufficient for ligation 3 to 5 minutes after polymerization but continued to increase 4 hours later. Increased failure in the present study could be the result of inadequate self-curing time.

The gap size between the tooth and the bracket might be a critical issue in failure rates. According to Eliades et al,[10] cyanoacrylate exhibited the highest cohesive bonding fractures (bonding material remains on the tooth and bracket surfaces) when compared with other conventional composite bonding products. This cohesive failure could be interpreted as a failure in the integrity of cyanoacrylate. The manufacturer recommended a thin layer of cyanoacrylate adhesive be applied to the bracket to improve bond strength. The gap between the tooth and the bracket can sometimes be too large because of variable tooth morphology; this might affect bond strength. In addition, manufacturers create different bracket bases designed to maximize bracket–bond success.[11-13] A different design might be needed when working with cyanoacrylate.

The results from this clinical trial are consistent with the recent ex vivo study by Al-Munajed et al,[3] who concluded that, owing to the high number of bond failures, cyanoacrylate is unsuitable for orthodontic bonding.

No statistically significant difference was found for decalcification in the 2 systems. Of the 2 materials examined, the manufacturer of the composite claims that this bonding agent has fluoride-releasing properties.[14] This study suggests that decalcification is similar for the 2 materials. The measure of decalcification with LightBond was similar to that found by Gaworski et al.[7]

CONCLUSIONS

This prospective, in vivo study compared a cyanoacrylate orthodontic bonding agent with a traditional light-cured composite resin bonding agent. Enamel decalcification for teeth bonded with cyanoacrylate was similar to the composite. Although cyanoacrylate has been successful in a number of medical, dental, and nonclinical arenas, the large number of bond failures ($>$ 50%) in this study shows that cyanoacrylate is not a suitable bonding material for routine clinical orthodontic practice. This study demonstrates the importance of testing new bonding systems in vivo in several studies before using them in routine clinical practice.

REFERENCES

1. Bishara SE, VonWald L, Laffoon JF, Warren J. Effect of using a new cyanoacrylate adhesive on the shear bond strength of orthodontic brackets. Angle Orthod 2001;71:466-9.
2. Örtendahl TW, Örtengren U. A new orthodontic bonding adhesive. J Clin Orthod 2000;34:50-4.
3. Al-Munajed MK, Gordon PH, McCabe JF. The use of a cyanoacrylate adhesive for bonding orthodontic brackets: an ex-vivo study. J Orthod 2000;27:255-60.
4. Wilson RM, Donly KJ. Demineralization around orthodontic brackets bonded with resin modified glass ionomer cement and a fluoride-releasing resin composite. Pediatr Dent 2001;23:255-9.
5. Vorhies AB, Donly KJ, Staley RN, Wefel JS. Enamel demineralization adjacent to orthodontic brackets bonded with hybrid glass ionomer cements: an in vitro study. Am J Orthod Dentofacial Orthop 1998;114:668-74.
6. Hallgren A, Oliveby A, Twetman S. Fluoride concentration in plaque adjacent to orthodontic appliances retained with glass ionomer cement. Caries Res 1993;27:51-4.
7. Gaworski M, Weinstein M, Borislow AJ, Braitman LE. Decalcification and bond failure: a comparison of a glass ionomer and a composite resin bonding system in vivo. Am J Orthod Dentofacial Orthop 1999;116:518-21.
8. Wenderoth C, Weinstein M, Borislow AJ. Effectiveness of a fluoride-releasing sealant in reducing decalcification during orthodontic treatment. Am J Orthod Dentofacial Orthop 1999;116:629-34.
9. Bishara SE, Laffoon JF, VonWald L, Warren J. Effect of time on the shear bond strength of cyanoacrylate and composite orthodontic adhesives. Am J Orthod Dentofacial Orthop 2002;121:297-300.
10. Eliades T, Katsavrias E, Eliades G. Moisture-insensitive adhesives: reactivity with water and bond strength to wet and saliva-contaminated enamel. Eur J Orthod 2002;24:35-42.
11. Knox J, Hubsch P, Jones ML, Middleton J. The influence of bracket base design on the strength of the bracket-cement interface. J Orthod 2000;27:249-54.
12. Cucu M, Driessen CH, Ferreira PD. The influence of orthodontic bracket base diameter and mesh size on bond strength. SADJ 2002;57:16-20.
13. Willems G, Carels CE, Verbeke G. In vitro peel/shear bond strength evaluation of orthodontic bracket base design. J Dent 1997;25:271-8.
14. Reliance Orthodontic Products. Manufacturer's information. Available at: www.relianceorthodontics.com. Accessed April 4, 2003.