Thermal debracketing of single crystal sapphire brackets

By Frederick A. Rueggeberg, DDS, MS; and Petra E. Lockwood

Single crystal sapphire brackets have proven to be a successful esthetic treatment alternative to metal brackets in orthodontic treatment. However, the debonding of these ceramic brackets has sometimes been accompanied by iatrogenic tooth damage,[1,2] including the removal of enamel along with the bracket base. An alternative to removing the sapphire brackets intact is to mechanically grind them from the tooth surface.[1] This method is fraught with expense, both in time of removal and in cost of diamond burrs required to grind the brackets away.

Recently, thermal debracketing has been proposed for the removal of orthodontic brackets.[3,4] Thermal debracketing relies upon the application of controlled heat to the resin that bonds the bracket to the etched enamel surface.[3] This treatment has been demonstrated to be nondamaging to pulpal tissue as well as to enamel when used under specified research conditions.[4] The temperature required for bracket removal has been shown to be associated with both the resin/filler ratio as well as the chemistry of the monomer system involved.[5] Because of the variables associated with the debonding temperatures of various bonding resins, the specific bracket bonding material should be chosen at the time of treatment initiation if thermal debonding is to be used at case completion. Knowledge of the relative temperatures required to remove commonly used commercial bonding materials would be most helpful in the selection of an orthodontic bracket adhesive when thermal debracketing is anticipated.

The purpose of this research was to determine the thermal debonding temperatures required to remove single crystal sapphire brackets from etched bovine enamel using a wide variety of commercial orthodontic bonding agents.

Abstract

Because of their optical clarity, single crystal sapphire brackets provide an esthetic advantage over many other types of orthodontic brackets. However, debonding of these brackets has caused iatrogenic damage to enamel. Thermal debonding has been proposed for use in removing sapphire brackets without causing damage to teeth. This study determined the temperature required at the enamel/resin interface to thermally debond sapphire brackets from etched bovine enamel using 23 different commercially available orthodontic resins and one experimental product. The results indicate a wide range of debonding temperatures for the various resins. As a group, the powder-liquid materials had a statistically lower debonding temperature than the two-paste, the no-mix products, or the light-cured materials, for which the temperatures were all similar. This paper presents relative information a clinician can use in selecting an orthodontic bonding resin to minimize thermal damage to the teeth while debonding sapphire brackets.

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Key Words

Sapphire brackets • Debonding

Table 1
Products tested

Product	Type of curing system	Manufacturer	Lot #
Accubond	two-paste	GAC International, Central Islip, NY	none
Achieve Mix	two-paste	A-Company, San Diego, CA	SJ 1351
Challenge	two-paste	Ormco/Sybron, Glendora, CA	8K1
Concise	two-paste	3M Dental Products, St. Paul, MN	9CD1
Dynabond	two-paste	Unitek, Monrovia, CA	80388
Endur	two-paste	Ormco/Sybron, Glendora, CA	9H01
Force II	two-paste	American Orthodontics, Sheboygan, WI	SJ 1295
Phase II	two-paste	Reliance Orthodontics, Itasca, IL	68289
Solo-Tach	two-paste	Caulk/Dentsply, Milford, DE	818891
Achieve Light	light-cured*	A-Company, San Diego, CA	102389
Light-Bond	light-cured	Reliance Orthodontics, Itasca, IL	none
Spectrum	light-cured	American Orthodontics, Sheboygan, WI	SI 1207
Transbond	light-cured	3M Dental Products, St. Paul, MN	915PCA
Achieve No-Mix	no-mix	A-Company, San Diego, CA	AJ 1097
Advantage	no-mix	Ortho Organizers, San Marcos, CA	10489
Control	no-mix	Lancer Orthodontics, Carlsbad, CA	60289
Mono-Lok2	no-mix	Rocky Mountain Orthodontics, Denver, CO	60589
No-Mix:30	no-mix	American Orthodontics, Sheboygan, WI	AS 1262
Ortho-Loc	no-mix	GAC International, Central Islip, NY	none
Rely-A-Bond	no-mix	Reliance Orthodontics, Itasca, IL	108099
System 1+	no-mix	Ormco/Sybron, Glendora, CA	9F1
Unite	no-mix	Unitek, Monrovia, CA	80389
Bracket Bond	powder-liquid	GAC International, Central Islip, NY	1288
Quasar	powder-liquid	Rocky Mountain Orthodontics, Denver, CO	90501

*denotes an experimental formulation

Materials and methods

A total of 23 commercially available orthodontic bonding resins were used. One resin was an experimental product still under development. Table 1 lists the bonding materials used as well as their mode of polymerization (two-paste, no-mix, light-cured, powder-liquid).

The methodology used in the present research has been described elsewhere,[5] and consists of grinding flat the facial enamel of freshly extracted lower bovine teeth using 600 grit silicon carbide abrasive. Care was employed that no dentin was exposed during the flattening procedure. A flat surface was required to minimize differences in tooth configuration that could contribute to variations in shear strength results. The pulp of the tooth was removed through a large lingual access hole. A #2 round burr was used to drill through from the middle of the flattened facial enamel surface into the empty pulp chamber. A K-type thermocouple was passed through this hole from the lingual and held in position with light-cured composite such that the thermocouple junction was flush with the flattened enamel surface. The enamel on the flattened tooth face was etched with the acid contained in each resin kit according to manufacturer's instructions. The tooth was dried with oil-free air and a sapphire bracket (U1R STD .018 Starfire,™ The "A" Company, San Diego, Calif.) was bonded to the tooth following manufacturer's directions. The bracket was positioned in the middle of the flattened enamel and directly over the thermocouple. Five replications of bonded brackets using a fresh tooth and a new bracket for each test were prepared with each resin material. The freshly bonded bracket adhesive was allowed to cure at room temperature for 7 minutes after which the tooth and bonded bracket was immersed in water and stored at 37°C for 24 hours prior to testing. The time interval of 7 minutes was chosen because it was considered a clinically appropriate time after which a bracket is bonded

Table 2
Mean debonding temperatures
(Ranked in order of debonding temperature)

PRODUCT	SYSTEM	MEAN (° C)*	STD DEV
BRACKET BOND	p - l	45	5
QUASAR	p - l	50	5
ENDUR	2 - p	62	13
DYNABOND	2 - p	70	8
SYSTEM 1+	n - m	73	20
ACHIEVE MIX	2 - p	84	18
ACHIEVE LIGHT	l - c	90	22
ACHIEVE NOMIX	n - m	98	22
ORTHO-LOC	n - m	100	19
FORCE II	2 - p	110	23
NO-MIX:30	n - m	116	23
TRANSBOND	l - c	116	16
SOLO-TACH	2 - p	123	24
ACCUBOND	2 - p	127	32
UNITE	n - m	139	10
LIGHT-BOND	l - c	139	20
MONO-LOK 2	n - m	142	9
PHASE II	2 - p	153	16
RELY-A-BOND	n - m	154	13
SPECTRUM	l - c	154	36
CONCISE	2 - p	159	14
CONTROL	l - c	163	32
CHALLENGE	2 - p	166	29
ADVANTAGE	n - m	168	27

* = mean of 5 repetitions
p - l = powder-liquid
2 - p = 2-paste
n - m = no-mix
l - c = light-cured

and first exposed to saliva.

After storage, the teeth were mounted in brass holders using mounting stone such that the flattened tooth face was normal to the holder base. A mounted specimen was positioned in a holding jig and the flattened blade of a soldering gun (Model #09540406, Sears/Craftsman, Chicago, Ill.) was placed into the bracket slot. The soldering gun was balanced so that it exerted no force on the bonded bracket. The thermocouple output was connected to an electronic cold junction compensator (Model MCJ-K, Omega Engineering, Stamford, Conn.). The output of the compensator was fed to the X-axis of an X-Y recorder. A knife blade was lowered onto the top of the bracket and a load of 2.2 Kg (5 lb) was applied. The vertical position of the knife blade and load were monitored by a linear variable differential transformer (LVDT). The output of the LVDT was applied to the Y-axis of the X-Y recorder. Debonding was initiated by the application of current to the soldering gun. The debonding temperature was determined by calculating the thermocouple output at the moment the LVDT indicated a rapid drop of the knife blade and load. The soldering gun was cooled to room temperature prior to each debonding test to ensure a uniform heating rate of the gun. The thermocouple output was converted into temperature by reference to a K-type thermocouple calibration chart.[6] Figure 1 demonstrates the debonding testing apparatus.

The mean debonding temperature was determined for each of the five replications for each bonding material. A one-way ANOVA[7] (the independent variable being resin brand) was performed to test for the presence of significant differences in debonding temperatures among the 24 brands tested. Fisher's PLSD test[7] was used to test for significant differences in mean debonding temperatures between specific brands. The data for each mode of polymerization was grouped and a one-way ANOVA (the independent variable being resin curing mode)

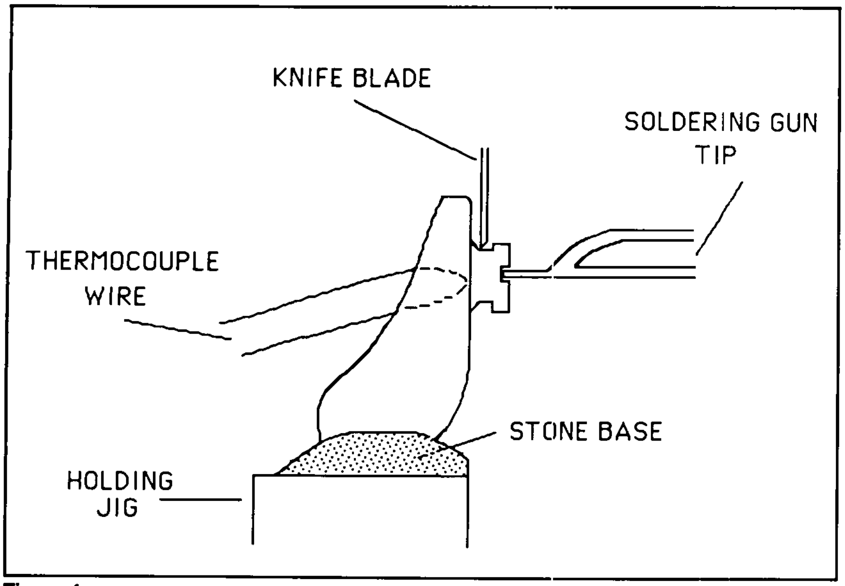

Figure 1

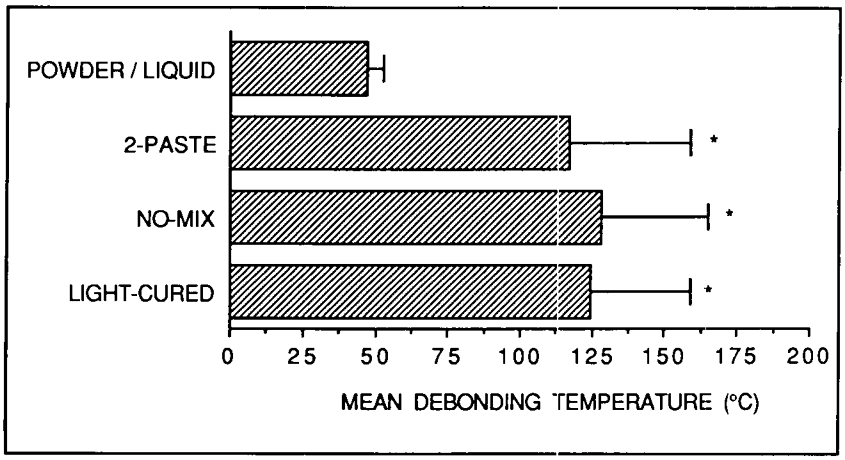

Figure 3

Figure 1
Diagram of debonding apparatus.

Figure 3
Mean debonding temperatures for the different types of polymerization systems. Bar represents one standard deviation. * represents groups with statistically similar values ($p<0.05$).

was performed to test for the presence of a significant difference in mean debonding temperatures among the different types of polymerization systems. Fisher's PLSD test was used to compare mean debonding temperatures within specific pairs of curing mode for significant difference. All statistical tests were performed at the 95% level of confidence.

Results

Table 2 displays the mean debonding temperatures of all brands tested. These temperatures ranged from a high of 168°C for the no-mix material, Advantage, to a low of 45°C for the powder-liquid product, Bracket Bond. Figure 2 shows the results of overall statistical differences among all of the products tested. For example, when comparing the debonding temperature of Bracket Bond with Control, there was a significant difference. However, the debracketing temperature of Bracket Bond compared to that for Endur was statistically similar. Of the light-cured products, half of the comparisons for mean debonding temperatures proved to be statistically different. Fifty-eight percent (21/36) of the comparisons for the no-mix systems proved to be statistically different. Sixty-nine percent (25/36) of the possible comparisons for the two-paste products indicated a significant difference in mean debonding temperatures. The two powder-liquid systems demonstrated no difference in mean debonding temperatures. Comparing debonding temperatures among the different types of curing systems (Figure 3), the only significant difference was the markedly lower temperature from the powder/liquid products.

In the great majority of cases, debonding failure occurred at the bracket/resin interface, leaving the bonding material remaining on the tooth. Debonding failures at the tooth/resin interface were infrequent and could not be attributed to any one bonding material or type of curing mode.

Discussion

It needs to be emphasized that the utility of debonding temperatures reported in this study is relative. The temperatures of debonding were not measured within the pulp. Instead, they were measured at the tooth/resin interface. However, it is reasonable to expect that a higher debonding temperature at the resin/enamel interface would create a greater potential for thermal influence on the pulp than would a lower temperature. Sheridan[4] demonstrated no significant histological changes in teeth from which brackets had been thermally debonded. The clinical use of a soldering gun for bracket debonding is neither suggested nor implied. The use of the gun enabled heat to be transferred to the brackets in a reproducible manner. A commercial electrothermal debracketing device will be marketed soon by a major dental manufacturer. It is on these bases that the results of this research can be compared and clinically applied.

The data suggest that the powder-liquid group demonstrated the lowest debonding temperatures. A similar trend in debonding temperatures was noted with the use of stainless steel brackets.[5] One of the main advantages of the powder-liquid system is that brackets are easy to remove and the tooth is left relatively undamaged. Ongoing research[8] however, had determined that the powder-liquid systems may permit bonded brackets to move after placement. At temperatures commonly found in hot consumed fluids, brackets bonded with a powder-liquid product were found to move under a low activating force (4 ounces).

In a previous study,[5] the two-paste products

Figure 2
Statistically different debonding temperatures within pairs of orthodontic resins.

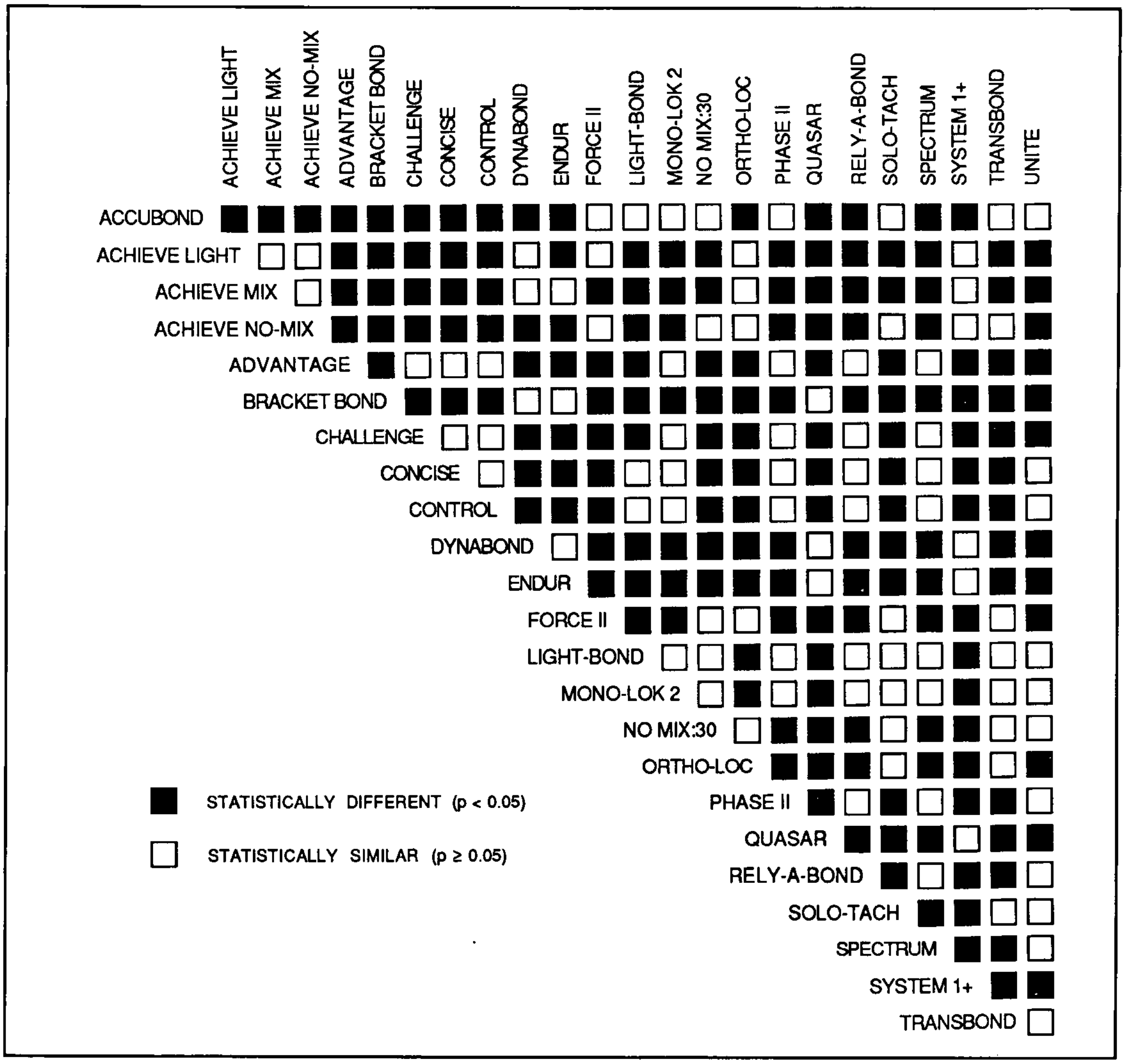

Figure 2

were found to have a markedly higher debonding temperature than the no-mix materials when debonding stainless steel brackets. This trend was not evident in the present research. Lack of distinction in debonding temperatures of these two modes of polymerization may arise from the larger number of brands tested in the present study, giving rise to a greater variability of results. An almost equal representation of no-mix, two-paste, and light-cured materials is demonstrated in the range of debonding temperatures from 60° to 170°C.

It is interesting to note that the use of light-cured orthodontic bonding resin is uniquely appropriate for use with single crystal sapphire brackets. Only peripheral curing is possible when using light-activated resins with stainless steel brackets. The other type of ceramic bracket (the polycrystalline alumina) is translucent and would be able to pass some light through its body to the underlying resin to provide curing. However, the intensity of radiation passing through the translucent product may be less then in that of the perfectly clear sapphire bracket because of light scattering. One light-cured material (Achieve Light, an experimental formulation) accomplished debonding at a relatively low temperature compared to the other light-activated systems. The advantage of light-curing brackets to teeth is three-fold: (1) light-curing saves clinical time because there is no mixing, and curing occurs in a matter of seconds; (2) light-curing is economical because excess resin can be removed prior to curing, greatly decreasing clean-up time; and (3) light-curing helps minimize bracket drift during placement, thus aiding in more accurate bracket positioning.

Conclusions

If thermal debracketing is anticipated when using sapphire brackets, it is important to know the relative thermal debonding temperature of a particular orthodontic bonding resin prior to placing the brackets. The lower the debracketing temperature, the less the potential for pulpal damage during debonding. Twenty-four commercial orthodontic bracket adhesives were tested for the temperature at which they caused thermal debonding of single crystal sapphire brackets using a debonding load of 5 pounds in shear. The debonding temperatures ranged widely from 45.1° to 167.6°C. As a group, the powder-liquid materials demonstrated significantly lower debonding temperatures than did the two-paste, the no-mix, or the light-cured products. Light-cured adhesives used with sapphire brackets provided similar debonding temperatures as the two-paste and no-mix materials.

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References

1. Swartz ML. Ceramic brackets. J Clin Orthod 1988; 22:82-88.
2. Swartz ML. A technical bulletin on the issues of bonding and debonding ceramic brackets. Ormco Technical Bulletin 1988 (April); 1-15.
3. Sheridan JJ, Brawley G, Hastings J. Electrothermal debracketing. Part I. An in vitro study. Am J Orthod Dentofacial Orthrop 1986; 89:21-27.
4. Sheridan JJ, Brawley G, Hastings J. Electrothermal debracketing. Part II. An in vivo study. Am J Orthod Dentofacial Orthrop 1986; 89:141-145.
5. Rueggeberg FA, Lockwood P. Thermal debracketing of orthodontic resins. Am J Orthod Dentofacial Orthrop 1990; 98:56-65.
6. Weast RC (editor). Handbook of Chemistry and Physics. Boca Raton, Fla.: CRC Press; 1987: E-107.
7. Statview 512+. Version 1.0 Calabassas, Calif.: Brain Power, Inc.; 1986.
8. Rueggeberg FA, Maher FT, Kelly MT. Thermal Properties of a Methyl Methacrylate-based Orthodontic Bonding Adhesive. Accepted for publication, Am J Orthod Dentofacial Orthrop, August, 1990.

Commentary
Thermal debracketing of sapphire brackets

By Robert J. Nikolai, PhD

This article reports the reduced and statistically analyzed data from an experiment in electrothermal debonding. Brackets were affixed to prepared facial surfaces of bovine teeth, subjected to a 5 lb force exerted occluso-gingivally and adjacent to the bond, and heat was transferred through the attachment to the bond, raising its temperature and thereby assisting the force in dislodgement. Independent variables were the bonding agent and preparation of the agent for fixation of the bracket (per vendors' recommendations). Constants were the facial surface preparation of the bovine enamel, the bracket, the applied force, and the heat-transfer process. Dependent variables were the temperature at which dislodgement occurred associated with 1) the bonding agent and 2) the category of the agent with regard to polymerization. A total of 24 bonding agents were tested. The raw data were reduced through one-way analyses of variance supplemented by an appropriate post-hoc test for significant differences in means.

The experiment was straightforward, apparently well controlled and, from comments within the text, seemingly a direct extension or companion to work reported recently in the *American Journal of Orthodontics and Dentofacial Orthopedics* (Reference #5). The results are restricted in that they pertain to just one specific bracket and a particular mechanical contribution to debonding.

The discussion section leaves some questions unanswered. For example, how does heat transfer differ between vital and non-vital teeth and between human and bovine teeth? The authors suggest only that the reported values of mean temperature provide relative indications of the ease of thermal debracketing; could the temperatures for some resins be too high for clinical use? And in actual use, should the thermal debonding failures still be expected at the sapphire bracket-resin interfaces?

The foregoing questions aside, the paper is a well-written synopsis of an interesting experiment, albeit of limited clinical applicability.