Electrothermal Bonding: Shear Bond Strength of Orthodontic Brackets After Two Weeks

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Abstract. *Electrothermal bonding is based on acceleration of the setting reaction of a bonding resin by the selective appli - cation of heat to the orthodontic bracket through the passage of a low voltage electric current. The purpose of this study was to compare the shear bond strength of nine resins comprising chemically-cured, light-cured, and glass ionomer types, 14 days after electrothermal and conventional bonding.*

Mean shear and bond strengths ranged from a low of 7.4 MPa for Sequence® (electrothermally bonded) to a high of 15.4 MPa Concise® (control). There was no statistically significant difference between the electrothermal and conventional bonding methods. All the resins produced bond strengths adequate for clinical orthodontics at 14 days.

Index words: Bond Strength, Electrothermal Bonding, Orthodontic Brackets.

Introduction

An essential requirement for successful bonding of orthodontic brackets, is the need to keep the field dry and to maintain the bracket in its correct position on the tooth surface without movement, until the bonding material has set. Movement of the bracket results in incorrect placement, and both movement and moisture disturb polymerization. The rate of the polymerization determines how soon the bond strength reaches a level sufficient for orthodontic forces to be applied to the bracket. There is a clinical advantage in being able to tie in an archwire in the shortest possible time after the bracket is bonded.

In 1979, Vorster described the concept of electrothermal bonding in orthodontics, the main aim of which is to reduce the setting time of the bonding material by heating the bracket. The polymerization of bonding materials responds to heat according to Arrhenius' equation, for every 18–20°F elevation, or reduction, in temperature, the speed of the chemical reaction doubles or halves, respectively (Vorster, 1979).

Stainless steel is a poor conductor of electricity (Blech, 1975); therefore, when an electric current is passed through a stainless steel orthodontic bracket, heat is generated due to the electrical resistance of the stainless steel. Electrothermal bonding uses a modified tweezer to pass pulses of a low voltage direct current through a stainless steel bracket held in the beak of the tweezers. Laboratory studies and clinical experience have shown that the underlying bonding resin sets after three or four pulses of current. Surface temperature ranged from 43·3°C to 53·6°C for 5 amps current, and between 77·5°C and 85·9°C using a 7·5 amp (Mizrahi *et al.*, 1996). Pulp chamber temperatures varied according to the thickness of the enamel and dentine labial wall. For a mandibular incisor with a comparatively thin labial wall, the temperature rise after 3 pulses was 2·1°C for 5 amps and 2·8°C for 7·5 amps current. Since studies have shown that a 5–7°C rise in pulp temperature is not harmful (Zach and Cohen, 1965; Goodis *et al.*, 1988), Mizrahi *et al.* (1996) concluded that the temperature increase in the pulp chamber during electrothermal bonding is clinically safe.

To determine the effect on the shear bond strength of electrothermal bonding, Mizrahi *et al.* (1994) tested a number of chemically- and light-cured resins. They measured the shear bond strengths achieved after 2 minutes. Most of the resins tested had bond strengths that were statistically significantly greater than the bond strengths of conventionally bonded specimens. Indeed, some of the electrothermally-bonded resins reached bond strength levels after 2 minutes that were almost 100 per cent of their maximum bond strengths. As yet no studies have evaluated the longer term bond strength after electrothermal bonding.

Objectives

The objective of this study was to measure shear bond strengths, after 2 weeks of conventional and electrothermal bonding.

Materials and Methods

Teeth

Eighty extracted caries-free human incisor teeth were cleaned under running water then stored at room temperature (22°C) in water containing a crystal of thymol to prevent dehydration and bacterial growth.

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Brackets

Flat-based, mesh-backed, Begg light wire brackets (TP#256-850 TP Orthodontics Inc, La Porte, Indiana, U.S.A.) were used for all the tests. The mean area of the bracket bases of 13·77 mm^2 (SD 0·13) was determined with a Kontron Videoplan Image Analysis System (Kontron Bild analyse GmbH, D-8057 Etching, Germany).

Electrothermal bonding unit

The electrothermal bonding unit was developed in conjunction with the Department of Electrical Engineering, University of the Witwatersrand. It consists of two components, a power source and a modified tweezer which delivers the current to the orthodontic bracket (Fig. 1). The features of the power source unit have been detailed elsewhere (Mizrahi *et al.* 1996). For the present study the settings were: a current level of 7·5 amps and a current flow of 1 second.

Tweezers

The tweezers are modified college tweezers with a brass terminal soldered at the hinge end of each blade to connect to the power source. The tweezer blades are insulated from each other with nylon.

Adhesives

Nine commercially available adhesive systems comprising chemically-cured resins, light-cured resins and glass ionomer resins were tested.

The four chemically-cured systems were:

1. Rely-a-Bond Primer/Paste system (Reliance Orthodontic Products, Ithaca, Ill. 60143 U.S.A.).
2. Concise Ortho Two-paste system (3M Dental Products, St. Paul, Minn. 55144, U.S.A.).
3. Super-C Ortho Powder-liquid system (Amco, West.Conshohocken, PA. 19428, U.S.A.).

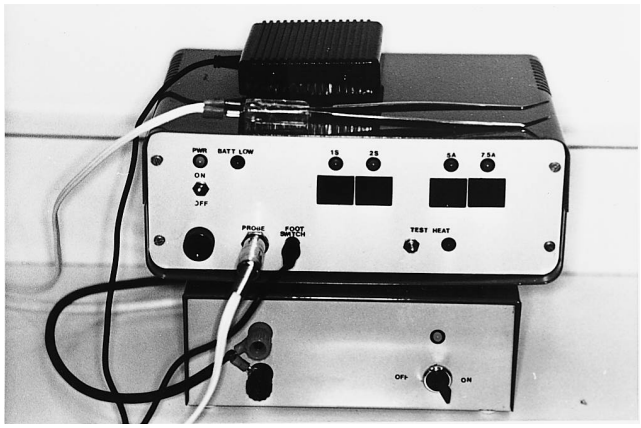

Fig. 1 Electrothermal bonding unit. On top are the foot switch and tweezers, in the middle is the control unit with settings for pulse time and current, and below is a power unit.

4. Nimetic Grip Two-paste system (ESPE GMBH, D-8031 Seefeldn/Oberbay, Germany).

The three light-cured systems were:

1. Transbond One-paste system (3M Corp., Monrovia, California, U.S.A.).
2. Light-Bond One-paste system (Reliance Orthodontic Products, Ithaca, Ill. 60143, U.S.A.).
3. Sequence Fluoride releasing One-paste system (Ormco, 1332S, Glendora, Cal. 91740, U.S.A.).

At the time of testing, there were no glass ionomer resin-based products produced specifically for orthodontic bonding so two glass ionomer materials were selected from cements used in restorative dentistry. These were:

1. Vitremer Powder-liquid system (3M Dental Products, St Paul, Minn. 55144, U.S.A.).
2. Dyract Compules tip system (DeTrey Dentsply, U.K.. Weybridge, Surrey, U.K.).

Specimens

The tooth roots were cut off with a water-cooled, high speed, air turbine after which the crowns were embedded in brass cups (9 mm diameter, 8 mm deep) with cold cure acrylic resin. These cups had a threaded base for attachment to a bracket fixed to the base of the Instron Bench testing machine (Instron Table Model 1026, Instron Ltd, Coronation Road, High Wycombe, Bucks HP12 35Y, U.K.). The labial surface of the embedded crown protruded slightly above the edge of the brass cup rim.

The enamel surface was ground flat to an area just larger than the bracket base, using a polishing machine and a wet 400 grit carborundum paper sanding disc (Kent Mark II, Engis Ltd, Maidstone, Kent, U.K.). The enamel surface of the embedded specimen was held parallel to the sanding disc and at right angles to the long axis of the brass cup with a jig.

The specimens were kept wet at all times; they were examined prior to each test and rejected as soon as the ground surface showed any exposed dentine. After each test the specimens were stored in water then reground and used for further tests (Mizrahi *et al.*, 1994).

After grinding, the enamel surface was dried with cotton wool, then etched, with 42 per cent phosphoric acid for 60 seconds. The etchant was removed by rinsing for 60 seconds with distilled water followed by drying with warm dry air using a hairdryer held approximately 40 cm away. The specimen was again checked to confirm that the enamel surface was intact, that no dentine was evident and that the etched enamel showed the characteristic frosty white appearance.

For each bonding material, 20 specimens were randomly selected and divided into two equal groups for the conventional bonding (control group) and the electrothermal bonding (experimental group). The sample size of 10 per group was determined by a statistical advisor and is large enough to show significant differences (Mizrahi *et al.*, 1994).

For all tests, the resins were mixed according to the manufacturers' instructions. For the one paste systems the liquid (primer or catalyst) was applied to the enamel surface and mesh base first. The bracket was held with the

modified tweezers used with the electrothermal bonding unit, the adhesive paste was placed onto the mesh of the bracket base, and the bracket was then pressed firmly onto the enamel specimen. Excess adhesive was carefully removed using a probe before polymerization. For all experimental groups the 7·5 amp current was applied for three consecutive, 1-second pulses with an interval of 2 seconds between the pulses. For the control group no current was applied.

Earlier research (Mizrahi *et al.*, 1994) showed that for the electrothermal bonding with light-cured resins, it is essential to first use the light to initiate the polymerization reaction after which it is possible to accelerate the reaction with electrothermal bonding. In this study, after the bracket and resin were seated on the prepared enamel specimen, polymerization was initiated with white light for 10 seconds. The electrothermal tweezers were then used to hold the bracket in position for the electrothermal bonding procedure.

All the specimens were left undisturbed for 5 minutes at room temperature (22°C) before being placed into a glass humidifyer which was sealed and stored for 2 weeks at 37°C.

Shear bond strength testing

The brass cups containing the embedded specimens were secured to a bracket attached to the base of the Instron machine and a shear load was applied to the bracket using a 0·5-mm stainless steel wire loop hooked under the archwire slot of the bracket at one end connected to the load cell at the other end. A cross-head speed of 50 mm/min was used.

The load was recorded graphically in kilogrammes. Using the 13·77 mm^2 surface area of the bracket and a conversion factor of 9·81 the stress values were converted to megapascals (MPa).

Data analysis

The data were analysed with SAS/STAT (1989) using a general linear models analysis with shear bond strength as the dependent variable and the resin and method as independent variables. This was followed by Tukey's multiple comparison test. The critical level of statistical significance was set at $P < 0{\cdot}05$.

Results

The shear bond strengths for the nine resins are listed in Table 1. For electrothermal bonding the highest bond strengths were in the chemically-cured group. In the conventional bonding group the lowest bond strengths were in the light-cured group. Statistical analysis was carried out within each resin group.

In the chemically-cured group, the general linear models analysis showed a statistically significant interdependence in bond strengths between the resins, but there was no significant differences between electrothermal and conventional bonding results. Tukey's multiple comparison test showed significant differences in mean bond strengths between Concise® and Rely-a-bond® as well as between Super-C® and Rely-a-Bond®.

Within the light-cured group there was a significant difference between the bonding methods, this disappeared when low bond strength values recorded for Light-Bond® were excluded. The shear bond strengths of the resins differed significantly from each other.

When the bond strengths of the glass ionomer cements were analysed, no statistically significant effects were found for resin brand or bonding method.

Discussion

The bonding resins selected for this study represent chemically-cured, light-cured and glass ionomer resin cements commonly used in clinical practice.

Bonding was to flat ground enamel surfaces to reduce the possible effect of uneven adhesive film thickness (Knoll *et al.*, 1986) also a more uniform etching pattern is likely on flat surfaces and specimens may be re-used without affecting bond strength significantly (Ledger *et al.*, 1989).

TABLE 1 Shear bond strengths in MPa

	14-day (current study)							
	n	Electrothermal		*n*	Conventional		2 min (Mizrahi *et al.* 1994)	
		Mean	SD		Mean	SD	Electrothermal mean	Conventional mean
Chemically-cured								
Rely-a-Bond®	10	11·8	2·9	10	10·9	2·5	5	3
Nimetric grip®	10	12·0	3·4	10	12·4	1·7	5	0
Super C®	10	14·6	1·3	8	12·4	2·6	17	14
Concise®	9	11·4	2·1	10	15·4	1·8	6	0
Light-cured								
Transbond®	10	10·3	2·5	10	9·6	2·7	10·1	5·1
Light-Bond®	10	1·9	1·5	10	8·9	4·1	4	1·6
Sequence®	8	7·4	1·7	7	11·3	2·9	7·9	3·7
Glass ionomers								
Dyract®	10	10·0	2·5	10	11·0	2·6	4·5	3·6
Vitremer®	10	9·9	1·7	10	11·1	1·1	4·5	3·0

When $n < 10$, for some specimens no result was obtained due to fracture of acrylic surrounding the tooth).

The optimum bond strength required for orthodontic bonding is not defined, but after a 2-year clinical trial Miura *et al.* (1971) concluded bond strengths of 5·1 MPa would be adequate for clinical use. In spite of the different bond strengths recorded for the different resins, all the resins except Light-Bond® (electrothermal bonding group) recorded bond strengths greater than this.

Within the chemically-cured resin group, the mean shear bond strengths for Rely-a-Bond® were higher in the experimental group (11·77 MPa) than in the control group (10·91 MPa). In contrast, the other three resins all had higher values in the control group. None of these differences reached statistical significance at the 0·05 level.

For a light-cured resin, polymerization must be initiated by exposure to white light (470-nm wavelength). Heat alone will not initiate this so it is necessary to first expose these cements to light. Once the reaction has started, the application of heat via electrothermal bonding should accelerate the reaction (Mizrahi *et al*., 1994). In this study a ten second exposure time to light was used which was sufficient for both Transbond® and Sequence®, but not recorded for Light-Bond®. If a longer light exposure time is necessary for Light-Bond® then adding the electrothermal technique is not recommended since the process would become too time consuming (Mizrahi *et al.*, 1994). The technique is most cost and time effective when used with chemically-cured resins.

With both bonding techniques, the bond strength values for the glass ionomer resins were well above the 5·1 MPa necessary for successful clinical bonding (Miura *et al.* 1971). The bond strengths of the glass ionomer resins tested in this study for both the groups had higher bond strengths than those of the unmodified glass ionomers tested in other studies (Fajen *et al*., 1990).

The bond strength 2 minutes after electrothermal bonding was shown in an earlier study to be significantly higher than that of the control specimen (Mizrahi *et al.*, 1994). However, the current study results show that after 2 weeks there is no longer any significant difference in the shear bond strength between specimens bonded with the electrothermal bonding technique and the control specimens bonded in the conventional manner.

The electrothermal bonding technique, with the accelerated rate of setting may offer clinical advantages with regard to the immediate bond strength achieved after 2 minutes with the accelerated rate of setting (Mizrahi *et al.*, 1994, 1995). The absence of any significant difference in the bond strength recorded after 14 days suggests that in using the electrothermal bonding technique there is no long-term advantage. However, the results of this study also show that the application of heat to the resins during the initial setting reaction does not appear to have any adverse effect on the long term bond strength.

Conclusions

The results of this study show that there is no significant difference in the shear bond strength recorded after 14 days between orthodontic brackets bonded with the electrothermal bonding technique and brackets bonded in the conventional manner.

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