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An *in vitro* study of the bond strength of light-cured glass ionomer cement in the bonding of orthodontic brackets

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SUMMARY The search to improve the properties of dental adhesives has lead to the development of light-cured glass ionomer cements. Using human teeth *in vitro*, the present study tested the shear/peel bond strengths of two light-cure materials ('Variglass VLC' and 'Fuji Lining LC') against a 'no-mix' composite orthodontic adhesive ('Right-On') and a chemically cured glass ionomer cement ('Ketac-Cem'). The light-cured materials were found to have an inferior bond strength compared with the two control adhesives. Based on the findings of this study, there is no evidence to support the use of the materials tested for the bonding of orthodontic brackets.

Introduction

Glass ionomer cement (GIC), first described by Wilson and Kent in 1972, has found widespread use in restorative dentistry as a luting cement and is currently used extensively for the cementation of orthodontic bands. The use of these cements for the direct bonding of orthodontic brackets has been described by White in 1986 and since then GICs have been assessed by a number of authors (Cook and Youngson, 1988; Klockowski *et al.*, 1989; Fox *et al.*, 1991; Øen *et al.*, 1991 and others).

The advantages of GICs to the orthodontist have been well documented (Cook, 1990; Özlem *et al.*, 1992) but the main obstruction to wider acceptance of the cements for the bonding of orthodontic brackets is their weak bond strength. Indeed, all the *in vitro* studies so far undertaken consistently draw the same conclusion that GICs have a weaker bond strength compared with the more commonly used composite resins. The search for improved physical characteristics, mainly in the field of restorative dentistry, has lead to the development of light-cured glass ionomer cements (LCGICs). These new materials have recently been tested *in vitro* for their use in orthodontics and this has resulted in differing recommendations on their application.

McCourt *et al.* (1991) tested a LCGIC with methyl methacrylate (Vitrabond) against a light-cured composite bonding resin and found it to have a significantly lower bond strength. The authors concluded that the LCGIC was not acceptable as an orthodontic bonding agent. Øen *et al.* (1991) also tested Vitrabond and did not show a favourable bond strength compared with chemically-cured GICs (Aqua Cem and Ketac-Fil) and a composite resin (Concise). Conversely, Rezk-Lega and Øgaard (1991) tested Vitrabond (a LCGIC) against two conventional GICs and found the LCGIC to be the strongest of the three tested, but the authors were doubtful if even this increased bond strength was of sufficient strength for clinical use. Compton *et al.* (1992) tested a LCGIC (Zionomer) against a chemically cured GIC. These authors concluded that the faster setting reaction of the LCGIC and its higher initial and sustained bond strength make it more attractive for use as an orthodontic bonding agent.

The purpose of the present study is to compare two new LCGICs against a commonly used 'no mix' composite resin and a chemically cured GIC. The study also investigated the manufacturer's claim that etching of the enamel prior to bracket bonding increases the bond strength of one of the materials (Variglass Dentspty, Milford, DE 19963–0359, USA).

Materials and methods

The method was that used in previous studies (Cook and Youngson, 1988, 1989). Sound premolar teeth ($n=50$), extracted from children for orthodontic purposes were collected and stored in distilled water. The teeth were mounted in acrylic blocks and colour coded into five groups of 10 teeth each. The buccal surface of each tooth was polished using a pumice and water paste and a premolar orthodontic bracket with a mesh base (Rocky Mountain, Denver, CO, USA) was bonded to each tooth by one of the following methods:

Group 1

First control group ('Right-On' TP Laboratories Inc., PO Box 73 La Porte, Indiana 4635a, USA).

- Etch for 60 seconds with 'Right-On' etchant (containing ortho phosphoric acid).
- Rinse the tooth with copious amounts of water.
- Dry with oil-free air stream.
- Bond the bracket according to the manufacturer's instructions.

Group 2

Second control group ('Ketac-Cem', Espe, Fabrik Pharmazeutischer Preparate GMBH and Co. KG, D-8031 Seefeld/Oberbay, Germany.)

- No pre-treatment other than the aforementioned prophylactic polish, rinse and dry the tooth with a cotton wool pledget.
- Bond the bracket, using a thick mix of cement as suggested by Cook (1990) and confirmed by Evans and Oliver (1991) and Frickler (1992). The thick mix was achieved by increasing 25 per cent more powder to the liquid than recommended by the manufacturers, i.e. 1.25 spoons of powder to 2 drops of liquid.

Group 3

First experimental group ('Variglass' etched).

- Etch the enamel surface as suggested by the manufacturer's instructions for 60 seconds.
- Rinse the tooth with copious amounts of water.
- Dry with oil-free air stream.
- Bond the bracket to the tooth using the thicker mix suggested by the manufacturer, using 1.5 large scoops of powder for 2 drops of liquid.
- Light cure for 40 seconds. This was the minimum time recommended by the manufacturer and the light source was applied for the whole of the time through the long axis of the tooth from the palatal aspect, as suggested by Read (1984).

Group 4

Second experimental group ('Variglass' unetched).

- This group was treated the same as for Group 3 with the exception of omitting the etching of the enamel.

Group 5

Third experimental group ('Fuji Lining LC' G-C Dental Industrial Corp., 76–1 Hasunuma-cho, Itabashi-ku, Tokyo 174, Japan).

- Rinse the tooth with copious amounts of water.
- Dry with oil-free air stream.
- Bond the bracket to the tooth using the thicker mix suggested by the manufacturer (powder/liquid ratio (g/g) = 1.7/1.0).
- Light cure for 40 seconds.

The bonding of all brackets was performed by the same operator (PAC) to a standardized technique. Each tooth was checked to ensure that the adhesive had been extruded from around the entire periphery of the bracket and any excess cement was carefully removed using a probe so that no cement overlapped the bracket base (this was done before light curing in Groups 3, 4 and 5). However, previous authors (Cook and Youngson, 1988) have demonstrated that the composite adhesives are not removed effectively by this method and tend to be 'smeared' over the surface of the tooth. Each bracket was then allowed to bench cure for 10 minutes and was then stored in water for 24 hours.

Each of the 50 colour-coded blocks was then given to another of the authors (CCY) who removed the colour coding and assigned each one a number and returned the blocks for subsequent testing. By this method the operator undertaking the bond strength assessments (PAC) was unaware of the adhesive used for any of the samples. With the exception of 'Ketac-Cem', which is white and opaque, the materials were all tooth-coloured and hence indistinguishable from one another.

The sheer/peel bond strength was tested on an Instron electromechanical tester (Instron Universal Testing Machine, Model 1195) using the method described by Cook and Youngson (1988). The acrylic blocks were clamped securely and the testing force was applied to the bracket by engaging a hook, constructed from 2 mm sheet steel, under the gingival tie wings of the bracket. The hook was attached to the Instron and the force (in Newtons) required to dislodge the bracket measured, using a crosshead speed of 0.5 mm/min. On completion of the testing of all 50 samples, the colour coding was revealed and the blocks allocated to their respective groups for statistical analysis.

The site of fracture was also investigated using a 'Magiscan' image analyser (Joyce Loebl, Dukesway, Team Valley, Gateshead, Tyne and Wear, NE11 OP2, UK) with an attached projection microscope. This provided an assessment of the amount of cement retained on each tooth and bracket (expressed as a percentage of the area of the base of the bracket) after the brackets had been dislodged in the bond strength test. All the image analyses were undertaken by the same operator (CCY). Although this author had allocated the numbers to the colour coded blocks, and was therefore not strictly 'blind' to the groups, it is considered unlikely that as there was some 4 weeks between the two stages this would have had any significant effect on the results.

Results

The results of the study are shown as mean values and SD in Table 1. The large SD, relative to the means for each group, indicate that the data are skewed. The results were, therefore, tested for differences between the materials using the non-parametric Kruskal–Wallis one-way analysis of variance (Table 2).

Table 2 Bond strengths calculated using the Kruskal–Wallis analysis of variance.

Group	Sample size	Median	Average rank	Z value
1	10	51.5	42.2	4.05
2	10	32.5	34.0	2.07
3	10	16.0	23.4	−0.51
4	10	3.0	5.7	−4.80
5	10	16.5	22.1	−0.81
Overall	50		25.5	

H = 35.80; d.f. = 4; P = 0.000 (adjusted for ties).

The results of the analysis of variance (ANOVA) show there are highly significant differences between the groups and the groups are ranked in the following order: Group 1 (Right-On) had the greatest bond strength, followed by Group 2 (Ketac-Cem), Group 3 (etched Variglass), Group 5 (Fuji LC) and finally Group 4 (unetched Variglass) which had the poorest bond strength.

Table 3 shows the mean and SD values for the area of cement, previously covered by the bracket, retained by the tooth. Similar data are shown for the area of cement retained by the bracket.

The data were analysed using a Kruskal–Wallis ANOVA and the results are shown in Tables 4 and 5. There were highly significant differences between the groups for both the amount of cement left on the tooth and on the bracket. Cement adherence to the tooth was best achieved by Group 1 (Right-On) with Group 4 (unetched Variglass) having the poorest adherence to the tooth. The amount of cement adhering to the bracket was greatest using the Fuji-LC (Group 5) while the brackets cemented using etched Variglass (Group 3) retained least of the five groups.

Discussion

The results for the two control adhesives in Groups 1 and 2 (Right-On and Ketac-Cem

Table 1 Bond strength of materials tested (Newtons).

	Group 1 ('Right On')	Group 2 ('Ketac-Cem')	Group 3 ('Variglass' etched)	Group 4 ('Variglass' unetched)	Group 5 ('Fuji LC')
Sample size	10	10	10	10	10
Mean	54.6	36.9	22.1	4.4	19.8
SD	20.8	14.04	13.96	2.95	9.39

Table 3 Percentage of cement retained.

	Group 1 ('Right On')	Group 2 ('Ketac-Cem')	Group 3 ('Variglass' etched)	Group 4 ('Variglass' unetched)	Group 5 ('Fuji LC')
Tooth					
Mean	68.97	18.55	21.95	9.96	23.49
SD	24.01	6.65	3.62	6.80	12.87
Bracket					
Mean	52.98	20.32	19.08	30.22	114.39
SD	23.37	3.42	4.78	4.48	42.29

Table 4 Cement remaining on the tooth; calculated using Kruskal–Wallis analysis of variance.

Group	Sample size	Median	Average rank	Z value
1	10	75.84	44.9	4.71
2	10	20.83	21.0	−1.08
3	10	22.04	27.0	0.38
4	10	8.52	9.2	−3.95
5	10	21.80	25.3	−0.05
Overall	50		25.5	

$H=31.26$; d.f. $=4$; $P=0.000$ (adjusted for ties).

Table 5 Cement remaining on the bracket; calculated using Kruskal–Wallis analysis of variance.

Group	Sample size	Median	Average rank	Z value
1	10	55.08	33.3	1.89
2	10	21.06	13.8	−2.84
3	10	19.49	11.4	−3.42
4	10	29.49	27.5	0.49
5	10	129.13	41.5	3.88
Overall	50		25.5	

$H=30.90$; d.f. $=4$; $P=0.000$ (adjusted for ties).

respectively) are in agreement with previous studies (Cook and Youngson, 1988; Klockowski *et al.*, 1989; Øen *et al.*, 1990, 1991; Fox *et al.*, 1991; Evans and Oliver, 1991; Rezk-Lega and Øgaard, 1991; Frickler, 1992) in that the composite resin had a significantly greater bond strength than the GIC. This has been the common finding in all previous *in vitro* studies in comparing these two groups of materials. However, Cook and Youngson (1988) did show that the GIC was able to withstand 83 per cent of the force required to dislodge a bracket bonded with composite resin and Øen *et al.* (1990) felt that the bond strength of one of the three GICs tested (Ketac-Cem) was adequate for clinical use.

The results for Groups 3 and 5 (Variglass and Fuji LC respectively) show that both materials have a very similar bond strength. However, both adhesives were shown to have lower bond strengths than the control Groups 1 and 2. This finding is in agreement with that of McCourt *et al.* (1991) and Øen *et al.* (1991), but is contrary to the findings of Rezk-Lega and Øgaard (1991) and Compton *et al.* (1992). The method of testing the bond strength is very similar in all such studies and it is unlikely that this would account for the differing results. It may be that the thickness of the mixed material influences its properties as suggested by Cook (1990). Evans and Oliver (1991) confirmed in an *in vitro* study that increasing the powder/liquid ratio resulted in a higher bond strength. Frickler (1992) in an *in vivo* study also showed that, with a thicker mix, a GIC was suitable for clinical use, but questioned whether the 20 per cent failure rate of the bracket bonds was acceptable compared with the failure rate of 5 per cent for the composite resin control group. However it is noteworthy that Cook (1990) showed a failure rate of 12.4 per cent with Ketac Cem *in vivo*. In the present study the thicker consistencies were used as suggested by the manufacturers because of the greater strength claimed.

An interesting finding was that the bond strength of Variglass was increased by etching the enamel before placing the cement. Cook and Youngson (1988) have previously shown such pre-treatment of the enamel to actually reduce the bond strength. Although this finding supports the claim of the manufacturer, it did not improve the property of the adhesive to a point equal to the Ketac-Cem group and only made it as strong as the Fuji LC. Acid etching of the enamel in association with Variglass (Group 3) increased the amount of cement retained by the tooth but there was a concomitant loss of material retained by the bracket when compared with the unetched Variglass samples (Group 4). This implies a material with low inherent adhesion to tooth or to metal brackets. The LCGICs did not exhibit significantly better adhesion to enamel than Ketac-Cem with roughly 20–25 per cent of the tooth, previously covered by the bracket, showing presence of cement following debonding. Variglass required etching of the enamel to produce a comparable result.

With the exception of Group 4 (unetched Variglass), the glass ionomer groups principally failed by adhesive failure at the tooth/cement and cement/bracket interface with simultaneous cohesive failure of the cement. Both the tooth and bracket then retained ~20–30 per cent cement. Group 5 (Fuji LC) however, showed retention of the cement by the bracket to a mean value of 114.39 per cent (as the cement overlapped the bracket area). In this group the failure was adhesive at the cement/tooth interface with only limited cohesive failure. It is not clear why this LCGIC should fail in a different manner to the other GICs studied, it can be speculated that the resin component which distinguishes many LCGICs conferred a greater cohesive strength to the Fuji LC.

Although the figures differ slightly, the current findings, where the composite group showed principally cohesive failure with some loss of adhesion at the cement/bracket interface, are in accordance with a previous study (Cook and Youngson, 1988).

The findings of the present study do not support the recommendation of the LCGICs tested and if the properties of GICs are to be utilized for the bonding of orthodontic brackets then the chemically-cured materials such as Ketac-Cem remain the best choice available at present.

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References

Compton A M, Meyers C E, Hondrum S O, Lorton L 1992 Comparison of the shear bond strength of a light-cured glass ionomer and a chemically cured glass ionomer for use as an orthodontic bonding agent. American Journal of Orthodontics and Dentofacial Orthopedics 101: 138–144

Cook P A 1990 Direct bonding with glass ionomer cement. Journal of Clinical Orthodontics 24: 509–511

Cook P A, Youngson C C 1988 An *in vitro* study of the bond strength of a glass ionomer cement in the direct bonding of orthodontic brackets. British Journal of Orthodontics 15: 247–253

Cook P A, Youngson C C 1989 A fluoride-containing composite resin–an *in vitro* study of a new material for orthodontic bonding. British Journal of Orthodontics 16: 207–212

Evans R, Oliver R 1991 Orthodontic bonding using glass ionomer cement: an *in vitro* study. European Journal of Orthodontics 13: 493–500

Fajen V B, Duncanson M G, Nanda R S, Currier G F, Angolkar P V 1990 An *in vitro* evaluation of bond strength of three glass ionomer cements. American Journal of Orthodontics and Dentofacial Orthopedics 97: 316–322

Fox N A, McCabe J F, Gordon P H 1991 Bond strengths of orthodontc bonding materials: an *in vitro* study. British Journal of Orthodontics 18: 125–130

Frickler J P 1992 A 12-month clinical evaluation of a glass polyalkenoate cement for the direct bonding of orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 101: 381–384

Klockowski R, Davis E L, Joynt R B, Wieczkowski G, MacDonald A 1989 Bond strength and durability of glass ionomer cements used as bonding agents in the placement of orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 96: 60–64

McCourt J W, Cooley R L, Bamwell S 1991 Bond strength of light-cure fluoride-releasing base-liners as orthodontic bracket adhesives. American Journal of Orthodontics and Dentofacial Orthopedics 100: 47–52

Øen J O, Gjerdet N R, Wisth P J 1991 Glass ionomer cements used as bonding materials for metal orthodontic brackets. An *in vitro* study. European Journal of Orthodontics 13: 187–191

Özlem S, Serpil H, Servet D 1992 The evaluation of enamel loss due to bonding of orthodontic attachments with a glass ionomer cement. European Journal of Orthodontics 14: 406 (Abstract)

Read M J F 1984 The bonding of orthodontic attachments using a visible light cured adhesive. British Journal of Orthodontics 11: 16–20

Rezk-Lega F, Øgaard B 1991 Tensile bond force of glass ionomer cements in direct bonding of orthodontic brackets: an *in vitro* comparative study. American Journal of Orthodontics and Dentofacial Orthopedics 100: 357–361

White L W 1986 Glass ionomer cement. Journal of Clinical Orthodontics 20: 387–391

Wilson A D, Kent B E 1972 A new translucent cement for dentistry. British Dental Journal 132: 133–135