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Scientific Section

An *Ex Vivo* Assessment of a Resin-modified Glass Ionomer Cement in Relation to Bonding Technique

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Abstract

Objective**: This study assessed a resin modified glass ionomer bonding system,* **Fuji ortho L.C.™** *using different bonding techniques and compared it with a composite control (Transbond™***).*

***Design**:* Ex vivo *study. Twenty extracted premolar teeth in each group were bonded as follows: (i) Group 1 Control (Transbond); (ii) Group 2 Fuji ortho L.C. without an etch procedure/wet enamel surface; (iii) Group 3 Fuji ortho L.C. without an etch procedure/dry enamel surface; (iv) Group 4 Fuji ortho L.C. using a conventional acid etch technique.*

***Outcome**: Shear bond strength, site of bond failure and adhesive remnant index.*

***Results**: Brackets bonded as recommended by the manufacturer (Group 2) have significantly ($p < 0{\cdot}001$) lower bond strengths compared with the control (Group 1). Bonding with an etch technique (Group 4) will significantly ($p < 0{\cdot}001$) increase the bond strength compared with the other Fuji groups. All the Fuji groups tended to fail at the enamel/resin interface with lower ARI scores compared with the control.*

***Conclusion**: The lower bond strength of Fuji ortho L.C. would limit its use as a routine bonding agent. When bonded with an acid etch technique, the bond strength may be sufficient for low loading situations such as the upper anterior teeth.*

Index words: Orthodontic Bracket Bonding, Resin-modified Glass Ionomer.

Introduction

Currently, the most commonly used adhesives for orthodontic bracket bonding are based on composite resin. However, glass ionomer systems have certain advantages. They bond directly to tooth tissue through the interaction of polyacrylate ions and hydroxyapatite crystals, thereby avoiding acid etching. In addition, they have a cariostatic action due to their fluoride leaching ability (Valk and Davidson, 1987; Hallgren *et al*., 1990). Nevertheless, their use in orthodontic bonding has been limited due to inferior mechanical properties, in particular bond strength (Fricker, 1992).

However, studies suggest that the new generation of resin-modified glass ionomer cements, which include varying amounts of a photocurable monomer, have improved properties including bond strength (Cook and Youngson, 1989; Chan *et al*., 1990; Rezk-Lega and Ogaard, 1991; Compton *et al*., 1992; McCarthy and Hondrum, 1994).

Furthermore, clinical trials have reported improved failure rates with these cements (Fricker, 1994; Silverman *et al*., 1995). Unfortunately, their failure rates were still significantly higher than conventional composite resin based adhesives.

The manufacturers recommend a non-etch bonding technique when using the resin-modified adhesive systems and also endorse a wet enamel field during the bonding process. From a clinical perspective, a bonding procedure that avoids enamel etching and does not rely on a dry field would be highly desirable with considerable time and cost savings. However, a recent study (Bishara *et al*., 1998) suggests that the bond strengths achieved may not be adequate to withstand normal occlusal loading.

In this *ex vivo* study we aimed to assess a currently available resin-modified glass ionomer adhesive (Fuji Ortho L.C.™, G.A.C. Corporation, Tokyo) to determine its bond strength in relation to the bonding technique used, as well as comparing it with a conventional composite adhesive control (Transbond™ 3M, St Paul, Mn, USA).

Methods

Eighty sound extracted premolar teeth were divided randomly into four groups of 20 teeth. They were mounted in polyester blocks with the long axis of each tooth vertical. The teeth were then bonded with pre-adjusted 0·022 3M Minitwin™ brackets using the following bonding techniques:

Group 1. The brackets were bonded with Transbond composite resin adhesive, using a conventional acid etch bonding technique. This group served as the control group.

Group 2. The brackets were bonded with Fuji Ortho LC™ without an etch procedure and to a wet enamel surface, as recommended by the manufacturer.
Group 3. The brackets were bonded with Fuji Ortho LC™ without an etch procedure and to a dry enamel surface.
Group 4. The brackets were bonded with Fuji Ortho LC™ using a conventional acid etch placement technique.

All the materials were mixed and applied according to the manufacturers instructions. Curing was carried out with a 60-second exposure to a blue light source (Visilux 2™, 3M, St Paul, Mn, USA). The bonded teeth were stored in distilled water for 1 week at 37°C to ensure complete polymerization. Following this, the teeth were debonded using the Instron Universal Testing Machine (Instron Ltd, High Wycombe, UK) as recommended previously by Fox *et al.* (1995). Following debond each tooth was examined under the stereomicroscope and the site of bond failure recorded along with the Adhesive Remnant Index (Artun and Bergland, 1984). This index consists of the following scoring: 0 = no retained resin, 1 = < 50% retained resin, 2 = >50% retained resin, and 3 = all resin retained with bracket imprint.

The data were analysed with analysis of variance and Tukey tests. Weibull analysis was also carried out. This relates probability of bond failure to the load applied. The use of this analysis has been advocated previously (Millet *et al.*, 1993; Fox *et al.*, 1995). The ARI data were analysed with chi-squared tests.

Results

The bond strength characteristics of the groups are shown in Table 1. The control group 1 (Transbond ™) had the highest mean and maximal debond values at 49·7 and 67·1 N, respectively. Group 3 (Fuji Ortho L.C.™ bonded to a dry enamel surface) had the lowest mean and maximal debond values at 18·5 and 32·2 N, respectively. ANOVA (Table 2) and Tukey tests (Table 3) confirmed that the bond strength results for the control group1 (Transbond™) were significantly higher ($P < 0{\cdot}0001$) compared with the Fuji groups. The results for group 4 (Fuji bonded with conventional acid etch technique) were significantly higher ($P < 0{\cdot}0001$) than those for groups 2 (wet enamel) and 3 (dry enamel).

Table 4 shows the Weibull modulus for the test groups. Group 1 (control) has the highest modulus at 5·9 and group 2, (Fuji/wet) the lowest at 2·2. The reliability of the material is a function of the Weibull modulus and normalizing parameter (characteristic strength). The correlation coefficient describes how closely the data fits the curve produced by the Weibull equation. The data is presented graphically in Figure 1 and consists of cumulative probability of bond failure against applied load. The probability of bond failure at 50 N was determined for each group (Table 4) as this approximated to the mean debond force level required to debond the control group (49·7 N). The probability of bond failure at 50 N was calculated at 49 per cent for the control group 1, 100 per cent for groups 2 and 3, and 83 per cent for group 4.

The bond failure sites (percentages of each group) are presented in Table 5 along with the adhesive remnant index (ARI) scores. The bracket/resin interface was the commonest site of failure for the control group 1 and group 4 (Fuji-etched). Conversely, the enamel/resin interface was the commonest site of failure for group 2 (Fuji-wet) and group 3 (Fuji- dry). Chi-square testing (Table 6) shows that there was a significant difference ($P < 0{\cdot}0001$) in ARI scores between the groups. Comparing the chi-square values for the individual groups (Table 6) demonstrates significantly higher values for the control group compared with the Fuji groups. This confirms that the Fuji groups had all significantly lower ARI scores and, therefore, less retained resin then the conventional composite control.

TABLE 1 *Bond strength of test groups*

	Control	Fuji (wet)	Fuji (dry)	Fuji (etch)
Mean	49·7	22·3	18·5	37·1
SD	8·7	9·3	7·8	12·3
SE	1·9	2·1	1·8	2·8
Max. value	67·1	40·3	32·2	55·0
Min. value	30·9	9·4	5·4	18·8

TABLE 2 *Analysis of variance between test groups*

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance
Between groups	12300·7	2·0	4100·2	43·6	< 0·0001

TABLE 3 *Statistical comparison of mean bond strengths (Tukey test)*

Means compared	Difference between means	Significance
Control + Fuji (wet)	27·4	< 0·0001
Control + Fuji (dry)	31·2	< 0·0001
Control + Fuji (etch)	12·6	< 0·001
Fuji (wet) + Fuji (dry)	3·8	None
Fuji (etch) + Fuji (dry)	14·8	< 0·0001
Fuji (etch) + Fuji (wet)	18·6	< 0·0001

TABLE 4 *Weibull analysis of test groups*

Group	Weibull modulus	SE	Normalising parameter (*n*)	Correlation coefficient	Probability of failure at 100 N
Control	5·9	0·27	53·5	0·96	49
Fuji (wet)	2·2	0·14	25·6	0·93	100
Fuji (dry)	2·3	0·04	21·1	0·99	100
Fuji (etch)	3·0	0·15	41·8	0·95	83

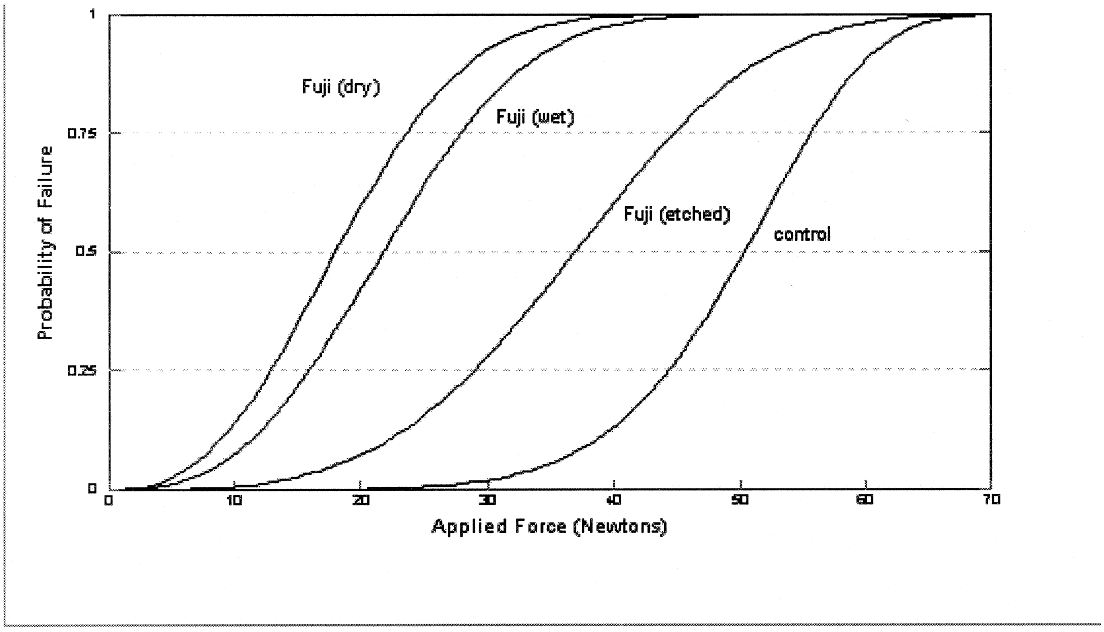

FIG. 1 Weibull curves for test groups.

TABLE 5 *Site of bond failure and adhesive remnant index scores for the test groups*

Group	Enamel/resin (%)	Bracket/resin (%)	Adhesive Remnant Index (total)
Control	10	90	40
Fuji (wet)	81	19	12
Fuji (dry)	78	22	12
Fuji (etch)	55	45	23

TABLE 6 *Chi square test for ARI scores*

Group	ARI score 0	ARI score 1	ARI score 2	ARI score 3
Control	4·7	2·5	9·0	11·3
Fuji dry	2·2	0·4	4·0	1·2
Fuji wet	2·2	0·4	4·0	1·2
Fuji etch	0·6	0·1	1·0	1·2

Groups 1, 2, 3, 4: chi-squared, 46·2; d.f. = 9; $P < 0·0001$.

Discussion

The manufacturers of Fuji Ortho L.C. recommend bracket placement on a wet enamel surface without carrying out a conventional acid etch procedure. This would obviously be very advantageous from a clinical point of view. However, the results of this *ex vivo* study suggest that brackets bonded in this way have lower bond strengths compared with a conventional composite control. Importantly, Weibull analysis suggests that 100 per cent failure will occur at 50 N compared with 49 per cent of the control. This seems to support the work of Bishara *et al*. (1998), who suggests that resin-modified cements may not have adequate bond strength to resist occlusal loading in the clinical situation.

Bonding with Fuji ORTHO L.C. using a conventional etch technique results in an increase in bond strength compared with the other Fuji groups. The probability of failure at 50 N being reduced to 83 per cent. However, its probability of failure is still higher than the composite control (group 1 = 49 per cent).

When we considered the site of failure, the percentage of brackets failing at the enamel/resin interface was increased for all the Fuji groups compared with the composite control. In the clinical situation, this would be advantageous, since less retained resin removal will be required at the end of treatment saving clinical time.

It would appear, therefore, that the significantly lower bond strength of Fuji Ortho L.C. limits its use as a routine bonding agent due to unacceptable bond failure rates. However, when combined with an acid etch technique, the bond strength may be sufficient for low loading situations, such as the upper anterior teeth. This would be very advantageous in patients with an increased caries risk status due to the cariostatic action of the fluoride release. However, its potential use would have to be assessed in a controlled clinical trial before its routine use could be recommended in this situation.

Conclusions

1. Fuji Ortho L.C. when applied as recommended has a lower bond strength and a higher probability of failure compared with the Transbond control.
2. It is suggested that in the clinical situation the use of Fuji Ortho L.C. may result in unacceptable bond failure rates.
3. The bond strength of the Fuji Ortho L.C. can be increased using an enamel acid etch technique, although it was still significantly lower than Transbond.

4. It is suggested that the bond strengths achieved with Fuji Ortho L.C. when combined with etching may be adequate in low loading clinical situations, but this would have to be confirmed in a controlled clinical trial.
5. Fuji Ortho L.C. groups will fail more often at the enamel/resin interface leaving less residual resin compared with the control. This would be advantageous from a clinical point of view, as less time would need to be spent carrying out enamel clean up at debond.

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