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The Effect of Food Simulants on Enamel–Composite Bond Strength

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Abstract *The effect of food simulants upon the enamel–composite bond strength of two orthodontic adhesive composites was studied. Thirty extracted premolars were used in each experimental group. Orthodontic brackets were bonded with either Transbond (3M Unitek) or Right-On (TP orthodontics) and were then exposed to either distilled water (control), 8 per cent ethanol (aqueous food), 50 per cent ethanol (alcoholic food), buffered lactic acid pH4 (acidic food), or corn oil (fatty food) for 12 weeks. Bond strength and Adhesive Remnant Index was recorded. It was found that 50 per cent ethanol had a significant effect upon the bond strength of both Transbond and Right-On. Right-On was affected to a greater extent. The clinical significance of this finding is that alcoholic mouth rinses, and alcohol-containing foods and drinks may be a causative factor in bond failure. However, the use of an alcoholic mouthrinse late in treatment may aid bracket removal. This potential use requires more research.*

Index words: Bond Strength, Food Simulants, Orthodontics

Refereed Scientific Paper

Introduction

Directly bonded fixed appliances have become the mainstay of modern orthodontics. Ease of bracket placement coupled with a reasonable clinical success rate and a reduction in chairside time has removed the need for banding all the teeth. However, there is a significant problem with bond failure during treatment, and this has been reported to vary between 0·5 and 16 per cent (Zachrisson, 1977; O'Brien *et al*., 1989). A number of possible causes have been proposed, including poor operator technique, saliva contamination (Mardaga and Shannon, 1982), variation in the enamel surface (Robinson *et al*., 1971, Hobson *et al*., in press), and masticatory forces (Zachrisson 1977).

Lee *et al.* (1994) reported the effects of oral fluid simulants and food simulants upon the bond strength of dentine bonding composites. They found that exposure to 75 per cent ethanol significantly decreased the bond strength after 30 days.

It has been shown that Bis-GMA based composites are susceptible to chemical softening by certain solvents (Wu and McKinney, 1982; Asmussen, 1984). McKinney and Wu (1985) found that food stimulants also affect the surface micro-hardness and wear characteristics of dental composites. It has been known for some time that dental composites are prone to degradation due to hydrolysis (Soderholm 1983; Oysaed and Rutyer 1986; Oilo, 1992). However, this softening and degradation has not been associated with increased bond failure rates in orthodontics as the average duration of orthodontic treatment is approximately 18 months, much shorter than the life expectancy of a dental restoration.

This investigation was performed to study the effects of known food simulants upon the bond strengths of two commercial orthodontic adhesives.

Materials and Methods

Three-hundred extracted human premolar teeth were collected and stored in 0·5 per cent aqueous Chloramine T solution until used. All were from white Caucasian children who lived in a fluoridated area in the North East of England. All teeth were non-carious and were extracted as part of orthodontic treatment. The extracted premolars were divided equally (so that there was equal number of upper and lower, first and second premolars in each group) into 10 groups of 30 teeth.

Two orthodontic dental composites were used in the study; namely, Transbond (3M Unitek Corporation, 2724 South Peck Road, Monrovia, CA 91016–5097, U.S.A.), a light-cured composite, and Right-On (TP orthodontics Inc, La Porte, IN 46350, U.S.A.), a two-component (liquid activator and paste), chemically-cured orthodontic bonding composite.

The food simulants were those recommended by the U.S.A. Food and Drug Administration for the effect of foodstuffs on materials (1988). They are:

1. Aqueous foods simulated by 8 per cent aqueous ethanol.
2. Alcoholic foods simulated by 50 per cent aqueous ethanol .
3. Acidic foods simulated by aqueous lactic acid buffered to pH4 .

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4. Fatty food simulated by corn oil.
5. A control was established using distilled water.

The buccal surface of each test tooth was cleaned using a pumice flour and water mix, and a dental handpiece and brush for 30 seconds. The teeth were then washed using a 3 in 1 (air/water) syringe, dried with compressed air and etched for 30 seconds on the buccal surface using 37 per cent phosphoric acid (Right-on) liquid etchant. The buccal surface was then washed for a further 30 seconds using a 3 in 1 (air/water) syringe, and dried with compressed air. Finally the tooth was dried with a warm air drier (Handi-dry, Lancer Orthodontics, U.S.A.) for a final 20 seconds prior to bonding of orthodontic brackets.

'A Company' 0·022-slot Andrews' prescription premolar stainless steel brackets (A Company, 11436 Sorrento Valley Road, San Diego, CA 92121–1393, U.S.A.) were used (the individualized brackets matched to the correct premolar). They were bonded with either Transbond (using the unfilled resin primer) or Right-On, and each material was manipulated according to the manufacture's instructions. The brackets were all placed in the middle of the buccal surface of the tooth. Transbond was light cured for 20 seconds from the mesial and distal surfaces of the bracket (total 40 seconds) using a 3M dental curing light.

The bonded teeth were stored in distilled water at 37°C for 24 hours, to allow full curing of both composites, before being placed into water or the chosen food simulant for 12 weeks. Substrates were changed weekly during the 12-week period and maintained at 37°C

At 12 weeks, each group of teeth were removed from their substrate, and mounted in cold curing denture base acrylic resin and bond strength was evaluated using an Instron machine (Model 5567, Instron, Coronation Road, High Wycombe, Buckinghamshire, HP12 3SY). A wire loop was placed under the lower wings of the bracket to apply the debonding force, as described by Fox *et al.* (1991). A cross-head speed of 1 mm/minute was used in all tests. The surface area of all brackets was measured using a Vernier micrometer and the mean surface area used to calculate the bond strength.

For each tooth/bracket tested the Adhesive Remnant Index (ARI; Artun and Bergland, 1984) was recorded. This gives the amount of composite adhesive remaining on the surface of the tooth and bracket as follows:

Adhesive Remnant Index

0 No adhesive on one surface
1 < 1/3 of surface covered
2 >1/3, but < 2/3 of surface covered
3 >2/3, but less than whole of surface
4 Whole surface covered

The ARI scores for the tooth and bracket are then totalled, and if the summation score is greater than 4, cohesive failure is implied. If the summed score is 4, the failure is adhesive. If the summed score is less than 4, this implies a void was present under the bracket. A score of 10 was recorded if enamel fracture had occurred.

Statistical analysis was undertaken using ANOVA and Tukey tests to examine for the effects of adhesive material and food simulants upon bond strength. Weibull analysis was used to determine probability distributions and determine debond probability. A Kruskal–Wallis test was used to determine significant differences amongst the ARI data.

Results

Mean bond strengths are given in Table 1. Both materials were significantly affected by the food simulants ($P < 0{\cdot}001$). In order to examine which food simulants have the greatest effect Tukey's pairwise comparison was undertaken for each material.

The Tukey tests show that 50 per cent ethanol (alcoholic food simulant) had a significant effect upon the bond strength of Right-On in comparison with distilled water (control), reducing the mean bond strength from 10·0 to 5·9 MPa.

The bond strength for Transbond was affected in a similar manner. However, the decrease in mean bond strength was less than that seen with Right-On, suggesting that Transbond was more resistant to degradation by food simulants. Only 50 per cent ethanol (alcoholic foods) had a significant effect upon the bond strength for Transbond.

Probability of failure as a function of stress is shown in Figure 1 (Transbond) and Figure 2 (Right-On). The curves confirm that 50 per cent alcohol had the greatest effect upon bond strength. The data were shown to fit a Weibull distribution curve, and the characteristic values and shape factors were calculated for each curve (Table 2). From these the probability of failure at both 5 and 10 MPa was calculated for each material and food simulant combination (Table 2).

The ARI data are presented in Table 3. The vast majority of bond failures were adhesive in nature (i.e. ARI 4). Cohesive failure was most common with 50 per cent ethanol. Corn oil storage resulted in the greatest number of enamel fractures. There was a significant difference ($P = 0{\cdot}01$) in the mode of failure between Right-On and Transbond; the latter having a greater number of cohesive failures and enamel fractures than Right-On.

Discussion

It has previously been reported by Wu and McKinney (1982) that food simulants, particularly alcoholic food simulants, have a softening effect upon the surface microhardness of dental composites. The finding of the present study confirms that the bond strengths of dental composites are significantly affected by alcoholic food simulants.

The two composites used in this study were not effected to the same extent. This may be due to differences in the composition of the materials, Transbond, being a light-

TABLE 1 *The effect of material and food simulant upon mean bond strength in MPa (S.D. in brackets)*

Simulant	Transbond	Right -On
Water (control)	10·9 (3·7)[a]	10·0 (3·4)[a]
8% ethanol (aqueous foods)	9·3 (3·4)[a]	8·8 (2·1)[ab]
50% ethanol (alcoholic foods)	7·6 (2·8)[b]	5·9 (2·3)[c]
Lactic acid pH4 (acidic foods)	9·6 (2·4)[a]	8·0 (3·2)[bc]
Corn oil (fatty foods)	10·7 (3·5)[a]	9·3 (3·2)[a]

Values with the same superscripts are not significantly different. $P > 0{\cdot}05$ ANOVA, Tukey test.

cured composite, does not require any mixing, whereas Right-On, being a paste and activator system, lends itself to possible inaccuracies in mix ratios, which in turn may affect the extent of polymerization.

Waldron and Causton (1991) proposed the use of peppermint oil to aid orthodontic bond and resin removal. However, Larmour and Chadwick (1995) reported that significant softening of resin only occurs after prolonged exposure to peppermint oil. The time period being clinically unacceptable. Larmour *et al.* (1998) examined the effect of peppermint oil, ethanol, and acetone upon ceramic bracket bond strength using Orthodontic Concise (3M Unitek). They reported that 1 hour's exposure to peppermint oil caused reduction in the mean bond

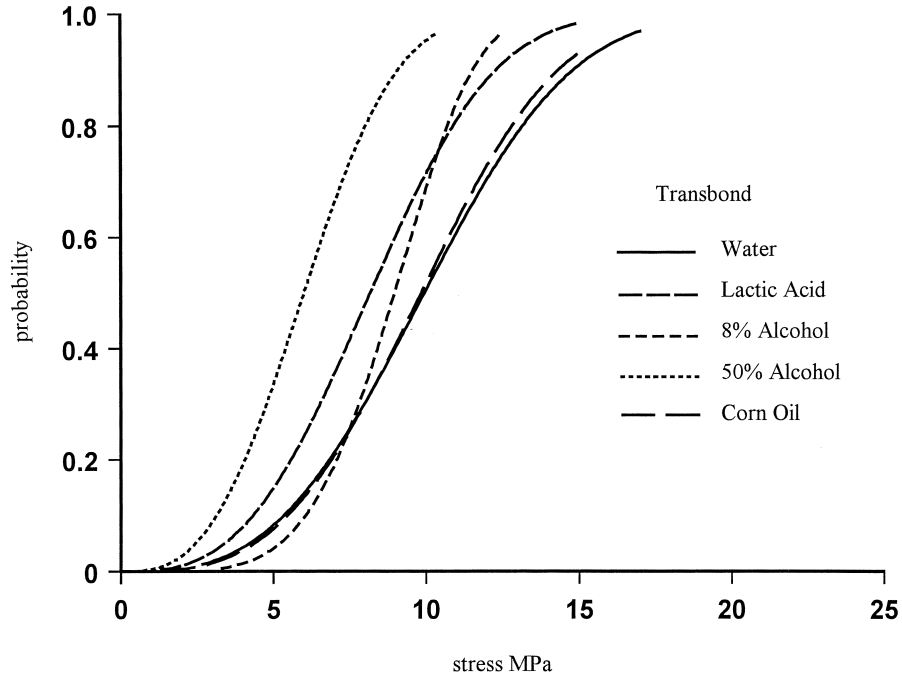

FIG. 1 Weibull distribution plots for Transbond.

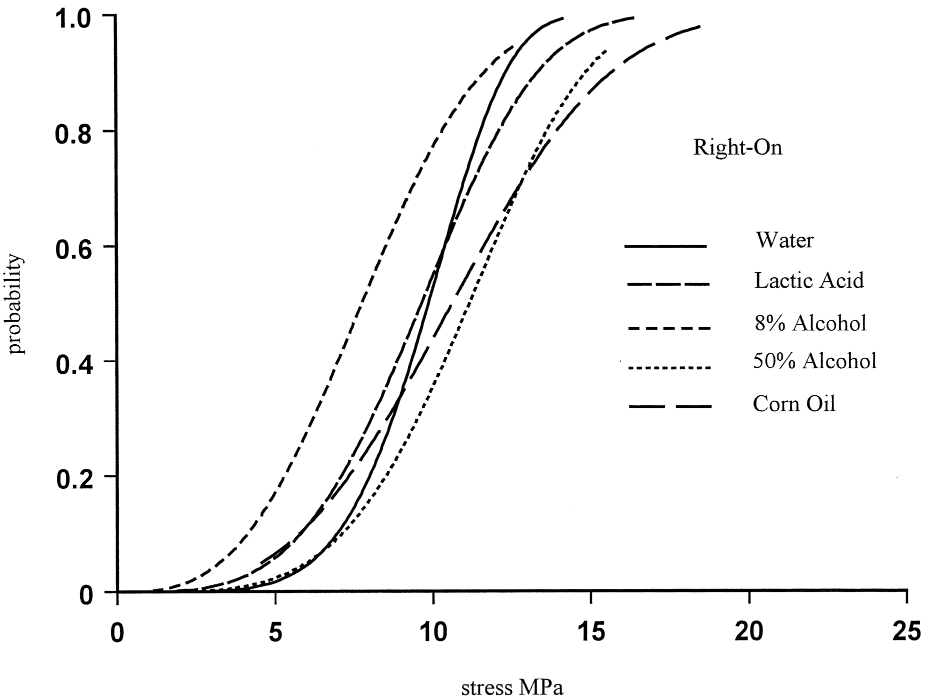

FIG. 2 Weibull distribution plots for Right-On.

TABLE 2 *The probability of bond failure of a bond at 5 and 10MPa. Values for the characteristic Weibull bond strength (*k*) and Weibull modulus*

Food simulant	Stress MPa	Probability of failure Transbond (%)	Weibull k(MPa)	Weibull m	Probability of failure Right-On (%)	Weibull k(MPa)	Weibull m
Water	5	6	10·6	5·4	8	11·2	3·0
(control)	10	43			51		
8% ethanol	5	6	8·8	3·0	4	9·7	4·8
(aqueous foods)	10	55			69		
50% ethanol	5	17	12·2	4·2	34	6·8	2·9
(alcoholic foods)	10	77			95		
Lactic acid pH4	5	2	10·6	3·7	15	9·3	3·0
(acidic foods)	10	52			72		
Corn oil	5	2	11·6	3·1	8	11·0	3·2
(fatty foods)	10	35			52		

TABLE 3 *Adhesive Reminant Index*

Food simulant	Material	Fracture	ARI Index 1	2	3	4	5	6	7
Water	Transbond	7	4	1	2	11	5	0	0
	Right-On	2	0	0	1	25	2	0	0
8% ethanol	Transbond	1	0	0	4	21	3	1	0
	Right-On	6	0	0	0	21	3	0	0
50% ethanol	Transbond	3	1	0	1	16	5	0	4
	Right-On	1	0	1	1	18	9	0	0
Lactic acid	Transbond	4	0	0	0	24	2	0	0
	Right-On	6	0	0	1	22	1	0	0
Corn oil	Transbond	8	0	1	1	12	8	0	0
	Right-On	9	0	1	0	14	6	0	0

Values in the table show the number of specimens having the specific ARI score.

strength, but the result was not significant. However, they did report that peppermint oil significantly increased the number of low ARI scores, resulting in less resin on the enamel surface, which may aid 'clean up' following bond removal. The results of Larmour *et al.* (1998) reported no effect upon mean bond strength when orthodontic bonds were exposed to acetone or ethanol for 1 hour.

In contrast, Lee *et al.* (1994) examined the effect of 75 per cent ethanol on shear bond strength of a number of dentine bonding composites. They found that shear bond strength was reduced by between 30 and 50 per cent in comparison with specimens stored in water. Lee *et al.* (1995) proposed that the effect was caused by the diffusion of ethanol into the composite, which resulted in micro-cracking. Ethanol has solubility characteristics similar to that of Bis-GMA and this may further promote the infusion of ethanol into the composite leading to greater damage. In this study, the composite was continuously exposed to the food simulants for 12 weeks. In the oral environment, exposure would be of much shorter duration and of a cyclical nature. This may result in a slower rate of damage to the composite.

Weibull analysis allows the results to be put in perspective as it enables the probability of bond failure at different levels of stress to be calculated. If a stress of 5 MPa is encountered, the failure rates vary between 2 per cent (Transbond with corn oil and lactic acid) and 34 per cent (Right-On with 50 per cent ethanol). Since the reported failure rate due to de-bonding is in the range 0·5–16 per cent (Zachrisson, 1977; Read and O'Brien,1990; Millett and Gordon, 1994; Millett *et al.*, 1998), this suggests that the data recorded here may help to explain some clinical observations.

Alcohol exposure could result from either alcoholic drinks or alcohol containing mouthwashes, and it may be prudent to advise patients to avoid alcohol-containing mouthrinses during orthodontic treatment. Alternatively, if bonds treated regularly with alcohol containing mouthwashes can survive *in vivo*, then the debonding may be rendered easier. The results not only gives information on how bond strength is affected by food simulants, but also may give an insight into potential aids to de-bonding of orthodontic appliances at the end of treatment.

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