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An *Ex vivo* Investigation into the Effects of Chemical Solvents on the Debond Behaviour of Ceramic Orthodontic Brackets

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Abstract: *The problems of ceramic bracket debond have been well documented. A peppermint oil material has been marketed previously as a debonding agent. This study assessed ex vivo the effects of peppermint oil application on the debond behaviour of ceramic brackets compared with ethanol and acetone which are recognized softening agents.*

Intrigue® brackets were bonded to 100 extracted premolar teeth. Groups of 20 bonded teeth were then placed in a test solution, control (distilled water), peppermint oil (5 minutes and 1 hour), acetone (1 hour), and ethanol (1 hour).

The teeth were debonded using an Instron® Universal Testing Machine and debond forces recorded. The site of bond failure along with the adhesive remnant index was recorded for each tooth.

One hour placement in peppermint oil produced the lowest mean and maximal debond forces (77 and 114 N, respectively). Weibull analysis showed that the probability of failure at 100 N was increased for the 1-hour peppermint group at 88 per cent compared with 52 per cent for the control.

Placement in peppermint oil produced the lowest levels of retained resin. There was no evidence of enamel fracture with any of the groups, but bracket fracture remained a problem.

Index words: Ceramic Brackets, Chemical Solvents, Debond.

Refereed Paper

Introduction

The removal of ceramic brackets at the end of orthodontic treatment continues to be a problem. The high bond strengths result in a higher incidence of enamel damage occurring at debond compared with conventional metal brackets. (Redd and Shivapuja, 1991). The other problem also frequently reported is that of bracket fracture due to the low fracture toughness of ceramics (Odegaard and Segner, 1988). If bracket fracture occurs then removal of the remaining bracket is difficult and often involves the use of a high speed cutting drill. This risks damage to the enamel surface, thermal injury to the pulp, and inhalation of ceramic debris by the patient.

Many methods have been developed in an attempt to overcome these debond problems including the use of lasers (Strobl *et al.*, 1992) and thermal techniques (Jost-Brinkman *et al.* 1992) with only limited success.

A chemical agent based on peppermint oil (P-de-A®, Oradent, U.K.) has been previously marketed for use as a debonding agent. It was claimed that a 2-minute application would facilitate the removal of ceramic brackets and also help remove residual resin from the enamel surface (Waldron and Causton 1991). However, previous work (Larmour and Chadwick 1995) suggests that there is only a significant softening effect when peppermint oil is applied to orthodontic bonding resin for a longer period.

The objective of this study was to investigate the effect of peppermint oil application on the debond behaviour of ceramic orthodontic brackets compared with ethanol and acetone which are known chemical softening agents (McKinney and Wu, 1985). It was hypothesized that ceramic bracket removal could be facilitated and debond complications reduced by the application of an effective chemical agent.

Method

One-hundred sound premolar teeth extracted for orthodontic purposes from patients under the age of 18 years were collected and decontaminated in 0·5 per cent chloramine T disinfectant solution prior to storage in distilled water in a refrigerator.

The teeth were divided into five groups of 20 teeth, each consisting of 10 maxillary and 10 mandibular premolars. The roots were then notched using a 'rosehead' bur in a contra-angle handpiece to aid retention prior to mounting in polyester resin blocks with the long axis of each tooth vertical.

The teeth were then cleaned using a pumice slurry, rinsed with water and dried with oil-free compressed air. The buccal enamel surfaces were etched with phosphoric acid gel for 60 seconds, washed for 60 seconds, and dried with compressed air. Each tooth was then bonded with

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the appropriate Intrigue® ceramic orthodontic bracket (Orthocare U.K. Ltd.) using Orthodontic Concise® (3M, St Paul, Mn, USA) bonding agent mixed according to the manufacturers instructions (Fig. 1).

The bonded teeth were then stored in distilled water at 37°C for a 1-week period to ensure complete polymerisation prior to testing. Twenty bonded teeth were then placed in each of the following test solutions at 37°C before debonding. .

(1) control, distilled water (1 hour);
(2) ethanol (1 hour);
(3) acetone (1 hour);
(4) peppermint oil (1 hour);
(5) peppermint oil (5 minutes).

The brackets were removed using a rectangular wire loop which was placed around the tie-wings and a shear load was applied using an Instron® Universal Testing Machine as recommended previously (Fox *et al.*, 1994).The debond force was recorded with the Instron® operating with a cross-head speed of 1 mm per minute.

Following debond each tooth was examined under the stereomicroscope and the site of bond failure, and any enamel damage recorded along with the Adhesive Remnant Index (Årtun and Bergland, 1984). This index consists of the following scoring: 0 = no retained resin, 1 = <50 per cent retained resin, 2 = >50 per cent retained resin, 3 = all resin retained with bracket imprint. In this study the index was modified to include a score of 4 for a fractured bracket.

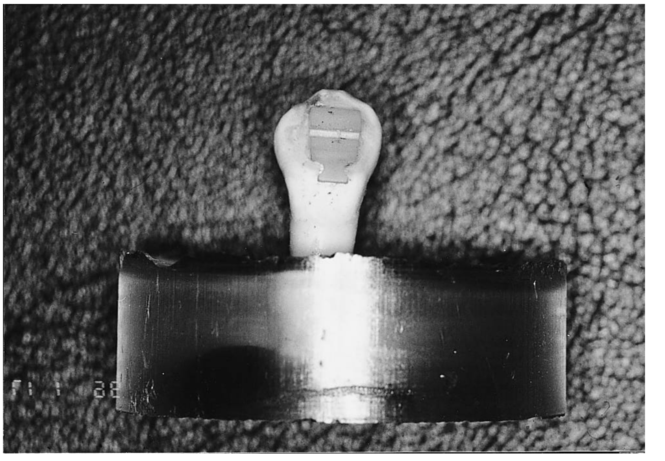

FIG. 1 Bonded tooth in polyester block prior to testing.

Results

The bond strength characteristics of the groups following placement in the appropriate test solution are shown in Table 1.

One-hour placement in peppermint oil produced the lowest mean and maximal debond values at 77·0 and 114·0 N compared with 103·7 and 200·0 N for the control group. Statistical analysis with ANOVA and Tukey tests however revealed no significant differences between any of the test groups.

Weibull analysis was also carried out. This relates probability of bond failure (debond) to the load applied. The use of this probability function analysis in bond strength testing has been advocated previously (Fox *et al.*, 1991; Millet *et al.*, 1993). The data is presented graphically in Figs 2 and 3 and consists of the cumulative probability of bond failure (debond) against applied load. The probability of failure at 100 N was determined for each group as this approximated to the mean force level required to debond the control group (103·7 N).

The probability of failure or debond at 100·0 N was calculated at 88 per cent for the peppermint oil (1 hour), 62 per cent for the peppermint oil (5 minute), 61 per cent for ethanol (1 hour), and 63 per cent for the acetone (1 hour) compared with 52 per cent for the control group. The bond failure sites (percentage of each group) are presented in Table 2 along with the adhesive remnant index (ARI) scores.

The bracket/resin interface was the commonest site of failure with all the groups except the peppermint oil group which tended to fail at the enamel/resin interface. There was no evidence of enamel damage in any of the groups. The peppermint oil groups had significantly lower ARI scores at 34 and 31 compared with the control group with the highest score at 61 ($P < 0{\cdot}001$ using ANOVA and Tukey tests). The bracket fracture rate was reduced to 15–20 per cent with the peppermint oil groups and 20 per cent with the acetone group compared with 40 per cent for the control group.

Discussion

It was decided to initially apply all the agents for a longer period than would be clinically acceptable (1 hour) so as to determine their maximum effects. The peppermint oil was also applied for a shorter period (5 minutes), since it has already been marketed as a clinical debonding agent. Previous work by Waldron and Caustron (1991) suggested

TABLE 1 *Bond strength characteristics of Intrigue® ceramic orthodontic brackets following placement in test solutions*

Group	Mean debond force (N)	S.D.	Weibull modulus	Maximal debond force (N)	Correlation coeffecient (R)	Characteristic force (N)	Probability of failure at 100 N (%)
Control	103·7	37·1	3·8	200	0·99	108·4	52
Ethanol (1 hour)	91·9	39·6	2·3	186	0·99	102·5	61
Acetone (1 hour)	87·2	34·1	2·3	140	0·99	100·1	63
Peppermint oil (1 hour)	77·0	18·0	3·9	114	0·99	84·2	88
Peppermint oil (5 minutes)	98·3	39·2	3·9	182	0·98	101·1	62

TABLE 2 *Site of bond failure and adhesive remnant index scores following placement in the test solutions*

Group	Enamel/resin (%)	Bracket/resin (%)	Bracket fracture (%)	Adhesive Remnant Index (Total)
Control	10	50	40	61
Ethanol (1 hour)	20	55	25	43
Acetone (1 hour)	35	45	20	48
Peppermint oil (1 hour)	55	25	20	34*
Peppermint oil (5 minutes)	60	25	15	31*

*$P < 0{\cdot}001$ with ANOVA and Tukey tests.

that peppermint oil could have an effect when applied for very short periods (1–2 minutes) but work by Larmour and Chadwick (1995) could find no appreciable composite softening effects at such short periods.

The results of the present study showed that a 1 hour placement of the bonded ceramic brackets in peppermint oil appears to facilitate ceramic bracket debond through reduction of the mean and maximal debond forces (77·0 and 114·0 N, respectively) compared to the control (103·7 and 200·0 N, respectively), but this was not statistically significant.

However, using Weibull analysis the probability of failure or debond at 100.0 N for the same 1-hour peppermint oil group was increased at almost 88 per cent compared with 52 per cent for the control group. The percentage of brackets failing at the enamel/resin interface was also increased with a corresponding decrease in the amount of retained resin as reflected in the lower ARI score. However, a significant per centage of brackets (20 per cent) still fractured during removal.

A 5-minute placement in peppermint oil had little effect on the mean debond force and the maximal debond force remained high at 182·0 N which was close to the control group maximum at 200·0 N. However, exposure to peppermint oil even for this shorter period of time did appear to affect the site of bond failure. Again the

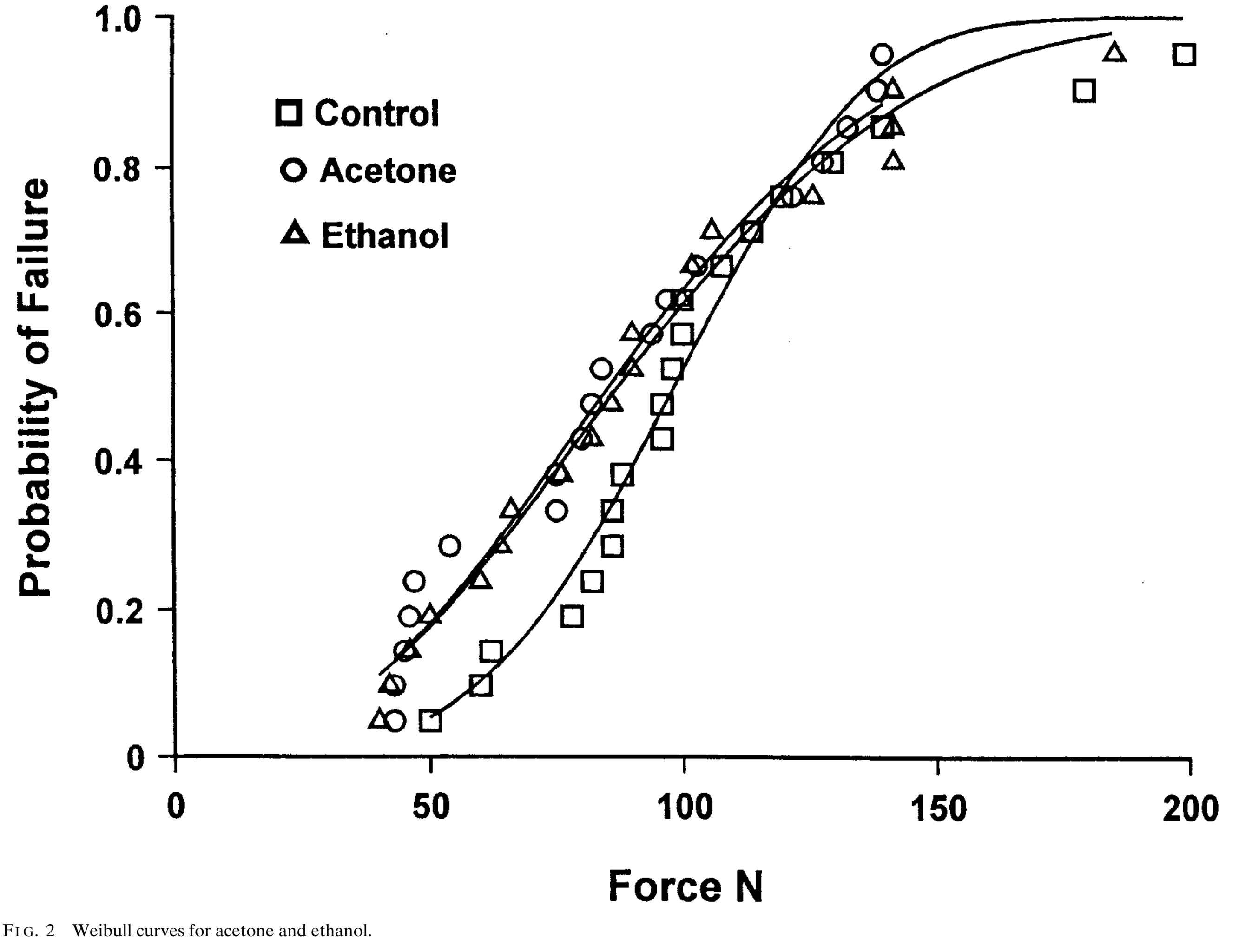

FIG. 2 Weibull curves for acetone and ethanol.

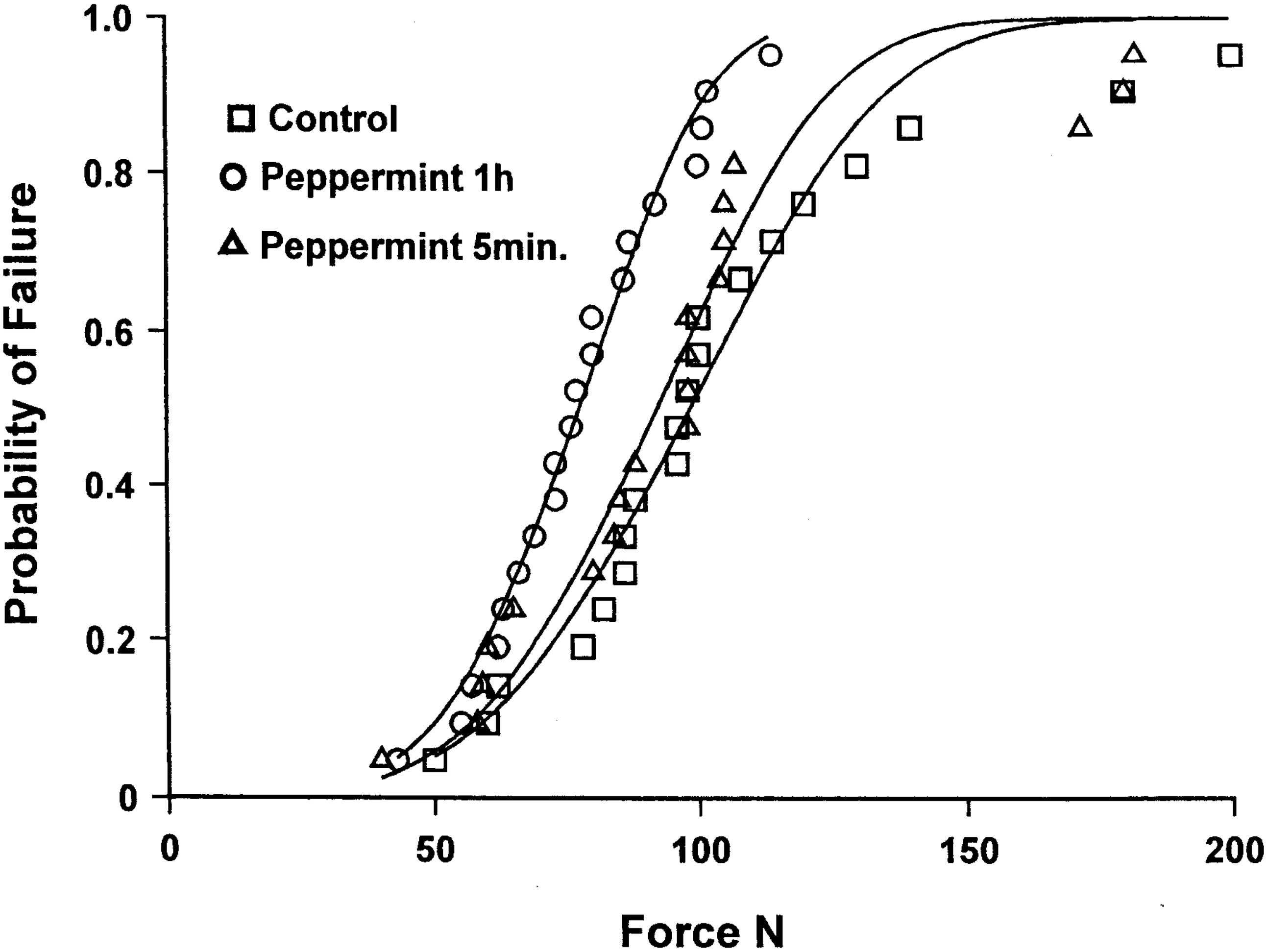

FIG. 3 Weibull curves for peppermint oil.

enamel/resin interface was the predominate site of failure with a corresponding low ARI score at 31.

From a clinical point of view this would be advantageous since less retained resin removal will be required at the end of treatment saving clinical time. The peppermint oil results in this study appear to provide some support for the work of Waldron and Causton (1991) who reported that the removal of ceramic brackets could be facilitated by applying peppermint oil. They suggested that the peppermint oil functions as a crazing agent and facilitates crack propagation through the composite bond layer. However, the results of the present study suggest that although placement in peppermint oil appears to alter the site of bond failure, the forces required to debond remain high and bracket fracture is still a problem.

Placement in ethanol or acetone appeared to have a less significant effect on the debond behaviour with probability of failures of 61 and 63 per cent at 100·0 N, respectively. Neither group had any significant effect on the site of bond failure with the bracket/resin interface remaining the most frequent site. The ARI scores were lower than the control group, but this reflected a reduction in the incidence of bracket fracture, rather than an actual reduction in the amount of retained resin. The bracket fracture rate remained high for the acetone and ethanol groups at 20 and 25 per cent, respectively. The potential toxicity of these agents would also preclude any clinical use.

No enamel damage was evident with any of the groups in this study, and this may be due to the Intrigue® brackets being mechanically retained. Previous work by Redd and Shivapuja (1991) reported lower debond forces and less enamel damage with mechanically retained brackets when compared with chemically retained brackets.

Conclusions

1. The results of this study do not conclusively support the hypothesis that ceramic bracket removal can be facilitated and complications reduced by the application of a chemical agent.
2. The application of peppermint oil for both the 1-hour period and shorter 5-minute period did increase the incidence of failure at the enamel/resin interface with less retained resin although bracket fracture was still a problem.
3. From a clinical point of view any reduction in the level of retained resin is advantageous since less time would be required for enamel 'clean-up' procedures following bracket removal. Further research would be

required in the form of a clinical trial to confirm the effectiveness of peppermint oil at reducing the levels of retained resin and saving clinical time before its routine use could be recommended.

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