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Notching of Orthodontic Bonding Resin to Facilitate Ceramic Bracket Debond—an *ex vivo* Investigation

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Abstract: This *ex vivo* study assessed the potential of introducing a notch in the bond layer, as a means of facilitating the removal of ceramic brackets. Sixty extracted premolar teeth were divided into three groups of 20 teeth and bonded with Intrigue® brackets using Concise® chemically-cured adhesive. The bonding technique was modified with groups 1 and 2 by introducing a notch in the bond layer. Group 1 was notched from the gingival aspect, group 2 from the occlusal, and group 3 served as a control.

The brackets were removed by applying a shear load from the gingival aspect using an Instron universal testing machine. The mean force to debond was calculated for each group.

The results showed that introducing a notch significantly reduced the mean and maximal debond forces. This was confirmed with Weibull analysis with the notched specimens having a higher probability of failure at any force. In addition, ceramic bracket fracture was eliminated.

Notching the bonding resin may be helpful in facilitating the removal of ceramic brackets

Index words: Ceramic Bracket Debond, Notching, Orthodontic Composite.

Refereed Paper

Introduction

Ceramic bracket debond problems, including bracket fracture and enamel damage have been well documented in the literature (Odegaard and Segner, 1988; Redd and Shivapuja, 1991).

A previous study (Larmour *et al*., 1998) has assessed, *ex vivo*, the potential of chemical solvent application to eliminate these debond problems. In that study, although levels of retained resin were reduced, bracket fracture remained a problem.

The present study aimed to assess the potential of introducing a notch in the composite bond layer as a means of eliminating ceramic bracket debond problems, including bracket fracture. It was hypothesized that introducing a notch into the composite bond layer would result in stress concentration at that point and propagation of a crack through the material on application of a debonding force, thereby facilitating ceramic bracket removal.

Methods

Sixty sound premolar teeth extracted for orthodontic reasons were stored in distilled water in the refrigerator following initial decontamination in 0·5 per cent Chloramine T solution. The roots were grooved to aid retention and mounted in polyester blocks with their long axis vertical. The teeth were divided into three groups of 20 each. The buccal enamel surfaces were prepared by cleaning with pumice and water, before drying and etching with 37 per cent phosphoric acid for 1 minute. Mechanically-retained ceramic Intrigue® (Lancer Pacific, Carlsbad, Cal. U.S.A.) orthodontic brackets were bonded using Concise® (3M, St Paul, Mn. U.S.A.) orthodontic bonding agent.

The bonding technique was modified for two groups of teeth. This modification involved placing an increment of bonding agent on the tooth surface and an increment on the bracket bonding surface. A section of Mylar® matrix strip (Dimensions = 0·01 mm thickness and 0·75 mm wide) was introduced between the two increments of bonding agent on either the gingival or occlusal aspect of the bracket as it was seated. Care was taken to ensure that the edge of the bracket base was flush with the matrix strip and that each bracket was seated using firm pressure. When the bonding agent had set, the section of matrix strip was removed carefully leaving a notch in the bond layer on either the gingival or occlusal aspect of the bracket (Fig. 1).

Twenty premolar teeth were set up as described with a notch on the gingival aspect (group 1) and 20 with a notch on the occlusal aspect of each bracket (group 2). The control (group 3) consisted of 20 teeth bonded as normal. The bonded teeth were then stored in distilled water for 1 week at 37°C to ensure complete polymerization. Following this, the teeth were debonded by applying a shear load from the gingival aspect using an Instron

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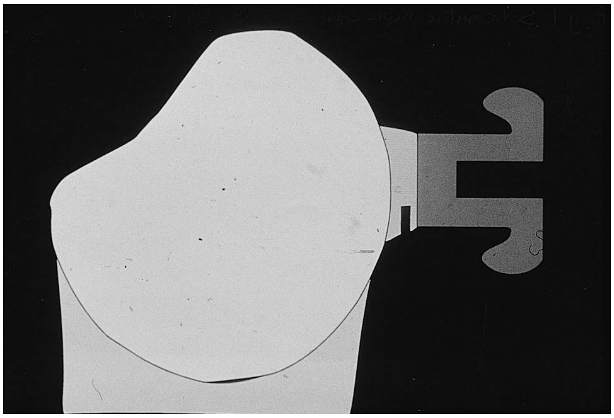

FIG. 1 Schematic diagram of 'notched' bond layer.

Universal Testing Machine utilising the method outlined by Fox *et al.* (1995). Each tooth was then examined under a stereomicroscope for evidence of enamel damage. The predominate site of bond failure was also recorded along with the Adhesive Remnant Index (Artun and Bergland, 1984).The adhesive remnant index (ARI) in the present study was slightly modified to include a score of 4 for a fractured bracket. The higher the score, the more material remained on the enamel surface following debonding. The ARI scores were recorded as follows:

0 clean enamel surface/no trace of resin
1 <50 per cent resin remaining
2 >50 per cent of resin remaining
3 all resin retained with bracket imprint
4 bracket fracture.

Results

The bond strength characteristics of the three groups are given in Table 1 which shows that group 1 (notch gingivally) had the lowest mean debond force value at 41·4 N and lowest maximal debond force at 64 N. ANOVA and Tukey statistical tests confirmed that both notched groups had significantly lower mean values than the control group ($P < 0{\cdot}001$). This was confirmed by Weibull analysis which relates probability of bond failure to the load applied.

Weibull distribution curves are presented in Fig. 2 and consist of cumulative probability of bond failure plotted against the applied shear debonding force for each group. The probability of failure or debond at 50 N was calculated at 69 per cent for group 1, compared with 23 per cent for group 2 and 5 per cent for the control group 3.

Table 2 shows the predominant site of bond failure and adhesive remnant index recorded after examination of the debonded surface using a stereomicroscope. The bracket/resin interface was the commonest site of bond failure during debond, accounting for 70, 60, and 50 per cent in groups 1, 2, and 3, respectively. A higher proportion of brackets failed at the enamel/resin interface in the notched groups, but the most significant finding was the elimination of bracket fracture in these groups compared with a fracture rate of 40 per cent with the control group. There was no evidence of enamel damage with any of the groups.

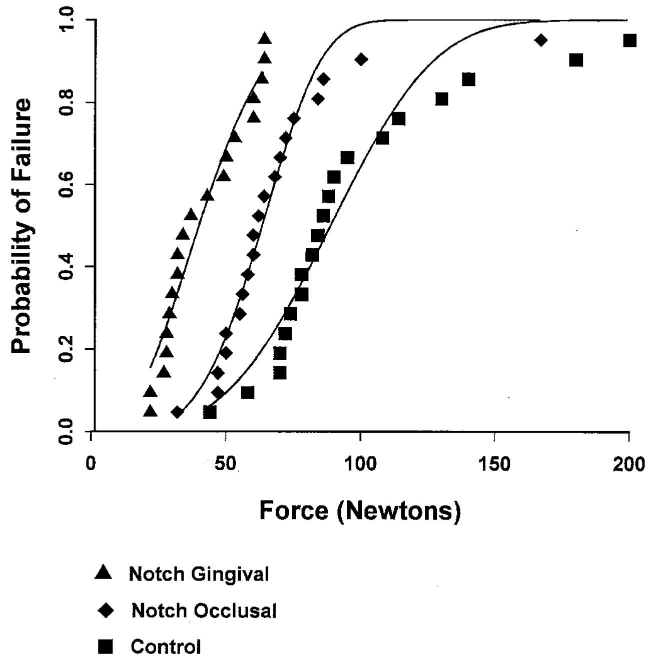

FIG. 2 Weibull Curves for notched and control groups.

Discussion

Many attempts have been made to overcome the debond problems of ceramic brackets. The introduction of mechanically retained brackets has reduced the debond forces required, but up to 30 per cent of the brackets will still fracture (Redd and Shivapuja, 1991).

Other methods introduced include the use of thermal debonding devices (Rueggberg and Lockwood, 1990) and specialized pliers (Bishara and Truelove, 1990), but bracket fracture is still a problem and the thermal devices have the potential of causing pulp damage (Jost-Brinkman *et al.*, 1992).The present study has shown that introducing a point of weakness/notch in the bond layer has a very significant effect on the debond behaviour of ceramic orthodontic brackets. Both the mean and maximal debonding forces are reduced; this is particularly the case when the notch is introduced in the direction of the debonding force. In the present study, the brackets were sheared off from the gingival aspect and the (group 1) teeth which were notched from the gingival had the lowest mean and maximal debond forces.

No enamel damage was reported in this study, and this is probably due to the brackets being mechanically retained. The brackets tended to debond at the bracket/resin interface thereby reducing the risk of enamel damage (Redd and Shivapuja, 1991).

Bracket fracture was not a problem with either of the notched groups compared with a 40 per cent fracture incidence with the control group. Presumably, the notch acted as a point of stress concentration in the bond layer and resulted in the propagation of a crack throughout its structure, thereby diverting the debonding force away from the brittle bracket structure.

No previous studies have assessed the effect of introducing a notch in the bond layer. The bonding technique

TABLE 1 *Bond strength characteristics for notched and control groups*

Group	Mean debond force (N)	SD	Weibull Modulus	Max. debond force (N)	Strength characteristic (N)	Probability of failure at 50 N (%)
1	41·4	15	2·4	64	46·7	69
2	68·1	28	4·1	167	69·2	23
3	103·7	37·1	3·8	200	108·4	5

TABLE 2 *Site of bond failure and ARI scores for notched and control groups*

Group	Enamel/resin (%)	Bracket/resin (%)	Bracket fracture (%)	ARI (total)
1	30	70	0	37
2	40	60	0	37
3	10	50	40	61

used in this study would not be feasible in a clinical setting due to the increased time and technical difficulty of introducing the notch. However, with further research into bracket base design it may be possible to modify the bracket base so that a point of weakness is automatically introduced into the bond layer when the bracket is bonded.

There is also the question of whether any weakening of the bond layer would increase the failure of the bracket during treatment. However, the mean bond strength of group 1 at 41·4 N is still similar to bond strengths reported by Sargison *et al*. (1995) using a different chemically-cured bonding agent 'Right-On' in the conventional manner.

The plaque retaining potential of such a notch may also be a disadvantage, although the use of a fluoride releasing bonding resin would help to reduce any associated caries risk.

Conclusions

1. Introducing a notch in the resin bond layer along the line of debonding force application (group 1) significantly reduces the mean and maximal debond forces.
2. Weibull analysis confirmed that the notched specimens are easier to debond with a significantly higher probability of debond at any force.
3. All groups showed a mixed mode of failure when examined under the stereomicroscope with the bracket/resin interface predominating. The bracket fracture incidence was 40 per cent with the control group, but was eliminated in both notched groups.

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