British Journal of Orthodontics/Vol. 26/1999/141–146

A Laboratory Investigation to Compare Enamel Preparation by Sandblasting or Acid Etching Prior to Bracket Bonding

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Abstract: *A laboratory investigation to compare the mean shear debonding force and mode of bond failure of metallic brackets bonded to sandblasted and acid-etched enamel is described. The buccal surfaces of 30 extracted human premolars were sandblasted for 5 seconds with 50 μ alumina and the buccal surfaces of a further 30 human premolars were etched with 37 per cent phosphoric acid for 15 seconds. Following storage for 24 hours at 37°C in distilled water, shear debonding forcewas measured using an Instron Universal Testing Machine with a cross-head speed of 10 mm/minute. Mean shear debonding force was significantly lower for brackets bonded to sandblasted enamel compared to acid etched enamel (*$P < 0.001$*). Weibull analysis showed that at a given stress the probability of failure was significantly greater for brackets bonded to sandblasted enamel. Brackets bonded to etched enamel showed a mixed mode of bond failure whereas following sandblasting, failure was adhesive at the enamel/composite interface (*$P < 0.01$*).*

Index words: Debonding Force, Etching, Orthodontic Brackets, Sandblasting.

Refereed Paper

Introduction

Since the work of Newman (1965) orthodontic brackets have been cemented to teeth with resin adhesives following enamel pretreatment with acid. However, the acid etch technique has several undesirable sequelae. These include loss of enamel due to prophylaxis, etching, debonding, and clean up; enamel cracks and scratches following debonding and retention of resin tags or indelible staining (Evans and Oliver, 1991).

A further disadvantage is the difficulty in confining the etchant to the area covered by the bracket base. In an effort to overcome the potential risk of decalcification which this poses, several studies have investigated the effects of reduced etching times or etchant concentrations on bracket bond strengths and failure rates. It would appear that etching for shorter durations or reducing acid concentrations results in less enamel loss (Barkmeier *et al.*, 1985; Legler *et al.*, 1990) and does not compromise bracket retention (Carstensen, 1986; Labart *et al.*, 1988; Legler *et al.*, 1989; Sadowsky *et al.*, 1990; Surmont *et al.*, 1992). However, the acid concentration should not be so low as to result in the formation of insoluble dicalcium phosphate dihydrate precipitates which are likely to interfere with the bonding process (Chow and Brown, 1973).

To overcome some of the problems presented by the acid etch technique, crystal growth solutions have been investigated (Pizarro *et al.*, 1994). These result in the formation of long needle-shaped crystals on the enamel surface, but bracket bond strengths tend to be inadequate (Artun and Bergland, 1984; Maijer and Smith, 1986).

Another possible means of enamel preparation is sandblasting. This technique has been used in orthodontics for treating the fitting surfaces of bands and brackets to enhance bond strength (Millett *et al.*, 1993) and for the removal of cement from failed brackets prior to recementation (Regan *et al.*, 1993). Only one study (Reisner *et al.*, 1997) to date has evaluated sandblasting as a method of enamel preparation prior to bracket bonding. With the development of miniature intra-oral sandblasters it would seem timely to explore this possibility further.

The aims of this study were:

1. In a pilot study, to examine the appearance of enamel surfaces, using scanning electron microscopy, following sandblasting and etching for similar time intervals, and to ascertain the optimal means of enamel preparation by sandblasting.
2. To determine the mean shear debonding force of orthodontic brackets following enamel preparation with either sandblasting or etching.
3. To analyse the mode of bond failure with both methods of enamel preparation.

Materials and Methods

Pilot study

The buccal surfaces of premolar teeth were either etched with 37 per cent phosphoric acid or sandblasted for, 5, 15,

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0301-228X/99/020000+00$02.00

30, 45, or 60 seconds. They were then observed using scanning electron microscopy to examine the morphology of the prepared enamel surfaces.

These preliminary electron microscopy results showed that the etched enamel surfaces demonstrated a classical, well defined 'honeycomb' or 'cobblestone' appearance (Figure 1). In this study, shorter etching times produced a cobblestone pattern and preferential dissolution of the prism peripheries, whereas longer etching times produced a honeycomb appearance and preferential dissolution of the prism cores, with greater depth of etching. Fifteen seconds etching was selected because significant etching was demonstrated on the scanning electron microscope photographs at this stage. Also, review of the orthodontic literature showed that, when using this relatively short etching time, bond strengths are not significantly reduced and enamel loss is more conservative.

Sandblasting produced a less well defined pattern on the enamel with irregular grooving of the enamel surface (Figure 2). Scanning electron microscopy showed that there was no apparent relationship between morphology and sandblasting time. Five seconds sandblasting was chosen because this would mimic what would be acceptable in the clinical situation.

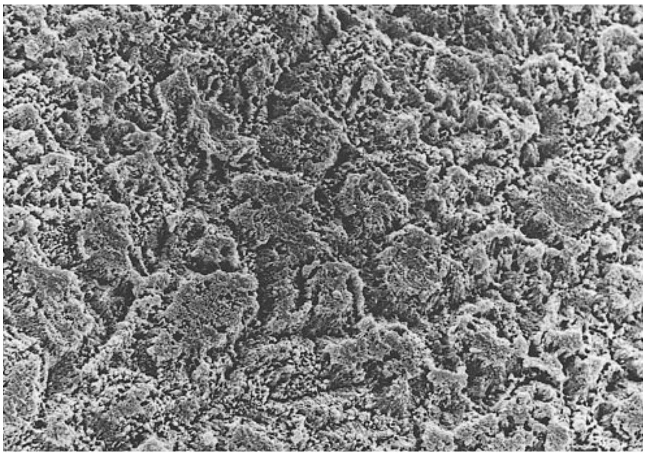

FIG. 1 Acid etching for 15 seconds.

FIG. 2 Sandblasting for 5 seconds.

Main study

Sound extracted human premolars were stored in distilled water in a refrigerator following decontamination in formalin. They were divided onto two groups of 30, each comprising 15 mandibular and 15 maxillary premolars The roots were grooved to aid retention and then mounted in polyester resin blocks with their long axes vertical and their crowns protruding. Following removal from the moulds, the buccal enamel surfaces were cleaned with a pumice slurry, washed in water, dried and treated by one of the following methods:

1 Etching: the buccal surfaces were etched with 37 per cent phosphoric acid solution for 15 seconds, washed, and dried thoroughly.
2. Sandblasting: the buccal surfaces were sandblasted with a micro-etcher (Ventura Oral Systems Limited, Halifax, UK) using 50 μ alumina for 5 seconds and then blown with air to remove any residual contamination.

The prepared buccal surfaces were bonded with a mesh backed, premolar stainless steel bracket ('A' Company, Orthologic, UK) using Right-on® (T.P. Orthodontics, Leeds, UK). This is a self-cured, lightly filled dimethacrylate resin. Excess composite was removed with a probe and the specimens were allowed to bench cure for 10 minutes. They were then immersed in distilled water in a humidifier at 37°C for 24 hours.

The shear debonding force required to debond the brackets was measured in Newtons using a cross-head speed of 10 mm/minute. A close fitting stainless steel wire loop was placed around the gingival tie wings and connected to the load cell of an Instron (Figure 3) using the method described by Fox *et al.* (1991).

The debonded brackets and enamel surfaces were examined for mode of bond failure under a stereomicroscope and several specimens were also observed using a scanning electron microscope. The most pre-

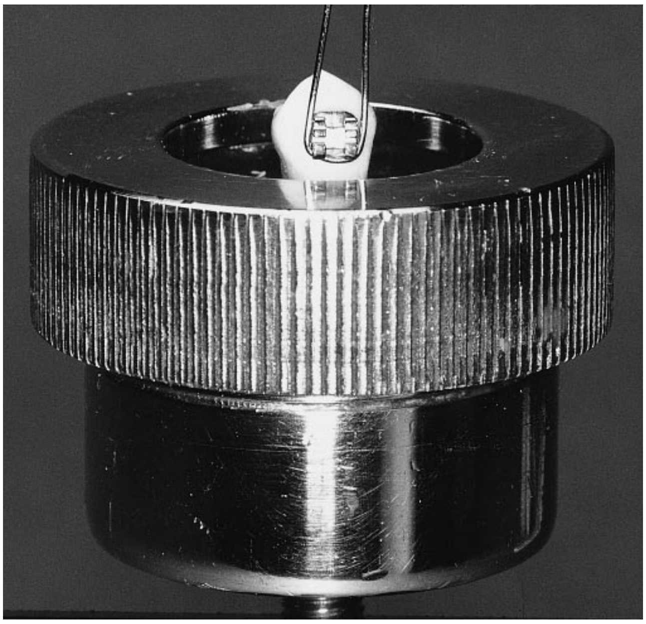

FIG. 3 Specimen for testing using an Instron.

dominant site of bond failure was recorded for each specimen, the categories recorded being; adhesive failure at the enamel/composite interface, adhesive failure at the composite/bracket interface, or cohesive failure in enamel or composite. The percentage of specimens failing at each site was calculated for the sandblasted and etched specimens.

Statistical Analysis

Mean debonding force, standard deviation, and standard error were calculated for each sample, and analysed using a *t*-test. Weibull analysis was used to calculate probabilities of failure at given values of applied force. Chi-squared analysis was used to compare the mode of bond failure.

Results

Debonding force data for etching and sandblasting are shown in Table 1. The mean debonding force for 15 seconds etching was 64.7 N and for sandblasting was 27.4 N. A *t*-test showed that the debonding force for etching was significantly higher ($P < 0.001$). Weibull analysis, which equates probability of bond failure with applied shear force has previously been used in bond strength studies (McCabe and Carrick, 1986; Fox *et al.*, 1991). Weibull data are also shown in Table 1 and demonstrated graphically in Figure 4. The Weibull moduli are 2.4 and 1.8, respectively, for etching and sandblasting. The lower value of modulus for sandblasting demonstrates less reliability for this method of enamel preparation. The high values of correlation coefficient of linearized least square fit indicate that the data closely fits the Weibull distribution function. The

TABLE 1 *Bonding characteristics for methods of enamel preparation*

Enamel preparation	Mean debonding force (N)	Standard deviation	Weibull modulus force (N)	Characteristic debonding of failure (N)	Force for 5% probability of	Correlation coefficient
Sandblasting	27.4*	15.6	1.84	29.7	5.9	0.98
Etching	64.7	24.9	2.42	72.9	21.4	0.99

Significantly lower; $P < 0.01$. *t*-test.

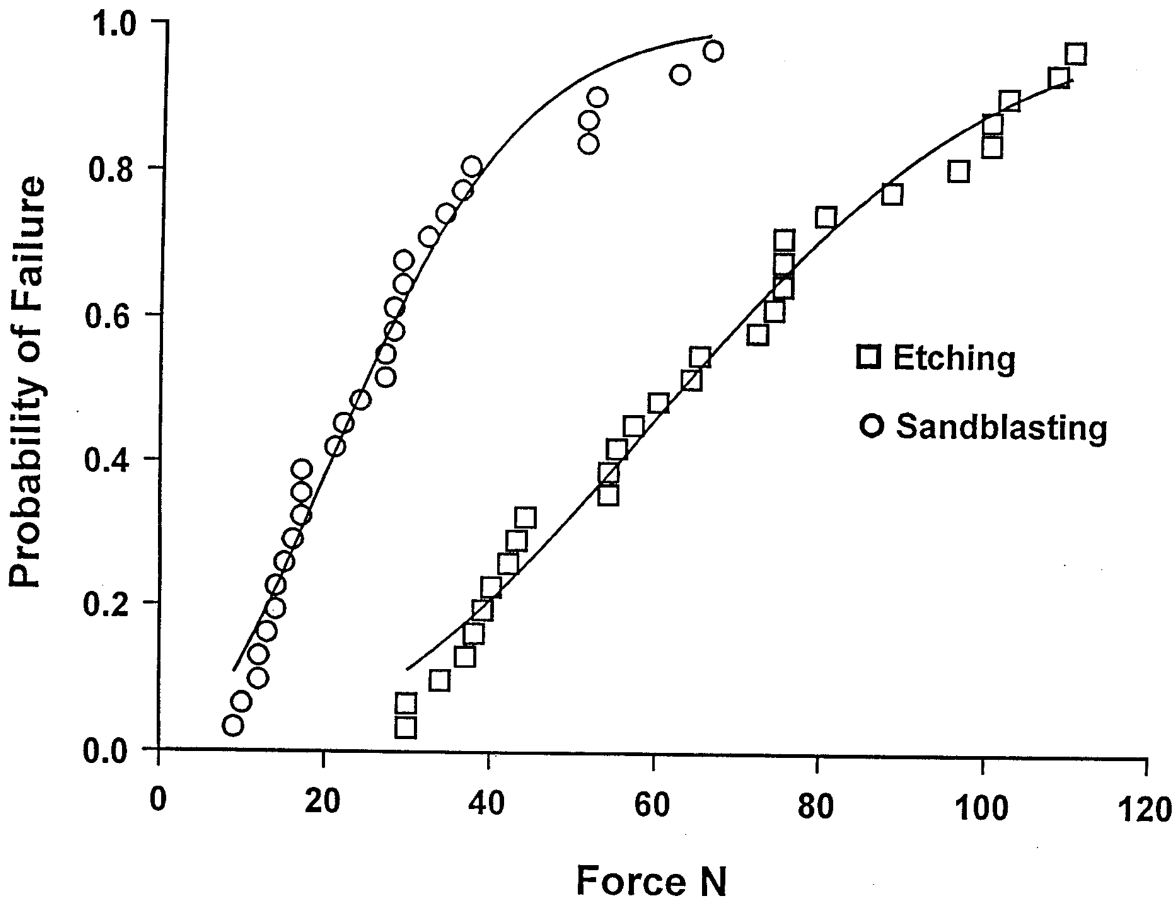

FIG. 4 Weibull curves for etched and sandblasted surfaces.

FIG. 5 Mixed mode of bond failure for etched specimen.

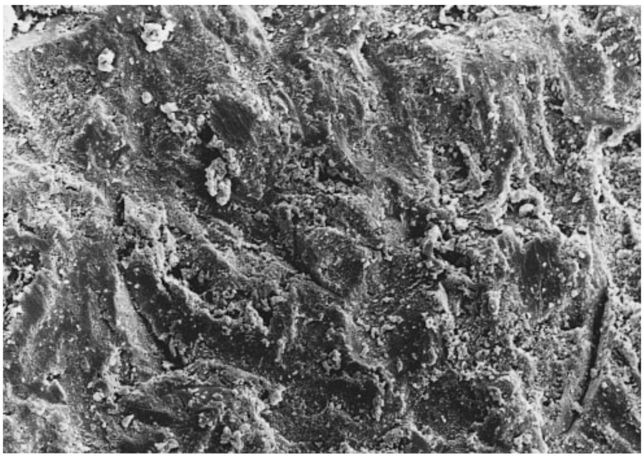

FIG. 6 Failure at the cement/bracket interface for sandblasted specimen.

graph illustrates that for a given probability of failure significantly more force would be required to dislodge a bracket cemented with Right-on® following 15 seconds enamel etching than with 5 seconds sandblasting.

Examination of mode of bond failure showed that the etched specimens tended to fail by a mixed mode of bond failure with some composite cement remaining on the enamel and some on the bracket (Figure 5). However, the sandblasted specimens showed adhesive bond failure at the enamel/composite interface (Figure 6) with minimal cement remaining on the enamel. Table 2 shows the data for mode of bond failure. Recording the predominant site of bond failure, all of the sandblasted specimens failed at the enamel/composite interface, whereas 19 (63 per cent) of the etched specimens failed at the enamel/composite interface and 11 (37 per cent) at the composite bracket interface. Recording the predominant site there were no cohesive failures within enamel or composite. Statistical analysis showed that these results were highly significant (Chi-squared = 13.47 on 1 df; $P < 0.01$).

TABLE 2 *Predominant site of bond failure (per cent) for each specimen*

	Sandblasting (%)	Etching (%)
Enamel/cement interface	100	63
Cement/bracket interface	0	37

*Significant Chi-squared = 13.47 on 1 df; P, 0.01.

Discussion

The mean shear debonding force for brackets bonded following 15 seconds etching was significantly greater than for 5 seconds sandblasting. Several factors may account for this difference, the morphology of the prepared enamel being the most likely.

Acid etching provides micromechanical attachment by a variety of means, ranging from preferential dissolution of the prism cores resulting in a honeycomb appearance to preferential dissolution of the prism peripheries resulting in a cobblestone appearance (Carstensen, 1992). Pitted or smooth etching patterns may also be produced. Preferential dissolution of the prisms can occur to a depth of 5–25 μ with the diameter of the defect ranging from 5–6 μ (Reynolds, 1975). On premolar teeth, honeycomb or cobblestone etch patterns are mainly exhibited in the central areas with pitted or smooth etching morphologies more commonly found in the cervical areas (Carstensen, 1992.) Varying the phosphoric acid concentration from 5 to 37 per cent has been shown to have a significant effect on the etch pattern with a reduced acid concentration resulting in less depth of etch (Bryant *et al.*, 1987; Legler *et al.*, 1990). However, there is little effect on bond strength (Legler *et al.*, 1989; Sadowsky *et al.*, 1990). Altering the etching times from 15 to 60 seconds, whilst maintaining a phosphoric acid concentration of 37 per cent also results in significantly less depth of etch (Barkmeier *et al.*, 1985; Legler *et al.*, 1990; Surmont *et al.*, 1992). Bond strength of bonded brackets is not compromised by the reduced etching times (Barkmeier *et al.*, 1985; Carstensen, 1986; Labart *et al.*, 1988; Legler *et al.*, 1989).

In relation to sandblasting, there has only been one previously published account describing its effect on enamel, apart from when described as air abrasion which appears to be synonomous. This uses a high velocity stream of alumina and air, producing a uniform roughness of the enamel up to 5 μ in depth, although individual defects ranging in width from 1 to 20 μ have been described (Laurell and Hess, 1995). On the other hand, air powder polishing uses a stream of air, water, and sodium bicarbonate (Barnes *et al.*, 1987), and produces non-uniform roughening of enamel (William *et al.*, 1980). A similar appearance was produced by sandblasting in the present study.

In this study sandblasting produced irregular grooving of the enamel with a less regularly defined pattern than that demonstrated with etching. Varying the particle size of the alumina and the duration of sandblasting could influence the morphology produced. We used a particle size of 50 μ provided and recommended by the manufacturer of the micro-etcher. A larger particle size may give different results. In relation to the duration of sandblasting, no difference was noted under SEM between enamel sandblasted for 5, 15, 30, 45, or 60 seconds. As a 5-second sandblast would be the only reasonable duration clinically (unless special precautions, e.g. rubber dam isolation were undertaken) this time interval was chosen for specimen preparation.

Following debonding, the brackets bonded to sandblasted enamel showed less composite remaining on the enamel surface than with acid etching. This is consistent with the mode of bond failure following crystal growth (Artun and Bergland, 1984) or with very low acid etch concentrations (Carstensen, 1993). Although this mode of bond failure would facilitate clean up following debonding and reduce the possibility of iatrogenic damage to enamel following this procedure, the weak bond strengths recorded with sandblasting enamel precludes its use clinically.

The mean debonding force for brackets bonded to sandblasted enamel was less than half that recorded for brackets bonded to acid etched enamel (27.4 and 64.7 N, respectively). Weibull analysis showed that there would be a 5 per cent chance of failure for brackets bonded to sandblasted enamel at a low force magnitude of 10 N. As forces applied clinically are likely to be well in excess of this, brackets bonded to sandblasted enamel would have an unacceptable clinical failure rate.

From this study the main disadvantages of sandblasting enamel are the unacceptably low debonding force in comparison to acid etching and the increased probability of bond failure at low levels of applied force. Sandblasting enamel is not recommended as a means of enamel preparation for orthodontic bonding, but is a useful technique to increase bond strengths when bonding to porcelain, amalgam or to gold (Zachrisson and Buyukyilmaz, 1993).

Conclusions

1. Brackets cemented with Right-on® following 15 seconds etching showed significantly higher mean shear debonding forces than following 5 seconds sandblasting.
2. Weibull analysis showed that for a given applied stress, the probability of bond failure was significantly less for etched enamel than for sandblasted enamel.
3. There was a mixed mode of bond failure for the brackets cemented following etching. Following sandblasting the specimens failed cleanly at the enamel/composite interface.

Acknowledgements

The authors would like to acknowledge the assistance of Dr T. E. Carrick in specimen testing, Ventura Oral Systems, Halifax, UK, for supplying the micro-etcher and Orthologic, UK for the provision of the 'A' Company brackets.

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