

A Quantitative Study of Enamel Acid Etch Patterns on Surfaces Used for Retention of Resin-bonded Fixed Prosthesis

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Abstract - This study investigated the quality of *in vivo* etch patterns on the bonding surfaces of 46 abutment teeth following acid etching with 37% phosphoric acid for 30 seconds. Two-stage putty and light bodied addition cured silicone impressions of the etched lingual surfaces were used to form replicas that were then viewed using the scanning electron microscope. Over 69% of the lingual bonding surface area of incisors, canine and premolars were unetched, 16% barely etched, 7% etched and less than 2% ideally etched. There was no significant difference in the quality of etch between different tooth types. There was a significantly greater proportion of poorly etched enamel towards the cervical margin in comparison with the occlusal half. This may have implications in retention of resin bonded bridges.

KEY WORDS: Denture, Partial, Fixed, Resin-bonded; Acid etch; Etch patterns

INTRODUCTION

The success of resin-bonded bridgework (RBB) depends upon the establishment of a durable bond between the bridge retainer and the etched enamel surface. Changes in resin-bonded bridgework technique reflect efforts to evaluate and improve adhesive agents, the bond to the metal retainer and the preparation and design of the bonding area. Although high bond strengths have been achieved *in-vitro*, this is not reflected clinically where the relatively poor survival of RBBs compared to conventional bridge-work¹ is frequently associated with an unpredictable and relatively high rate of bond failure².

The application of acid to the surface of enamel³ produces a distinct clinically visible change which at a microscopic level is referred to as the etch pattern. Various studies have examined the appearance of etched enamel. Poole and Johnston⁴ described differences in etching patterns produced when acids were applied to enamel. They noted that some areas displayed a preferential dissolution of rod core whilst leaving the periphery intact, whereas in other areas, the prism core was intact and periphery removed. This was thought to have been the action of the acid. However, Gwinnett⁵ and Silverstone⁶ showed that both of these etch patterns are found in areas of enamel exposed to acid alone, and are therefore characteristic of acid etching.

The etch pattern is thought to be related to the orientation of the enamel rods to the direction of acid attack. Apatite crystals dissolve in acid preferentially along their c-axis⁷, implying that those crystals perpendicular to the acid attack dissolve faster than those at a more oblique

angle do. Studies have shown significant differences in etch patterns obtained in the cervical third of premolar and molar teeth⁸. This was attributed to the presence of rodless enamel in this area. The etch pattern showed a pitted feature with no rod delineation regardless of etching time. The etched central and incisal enamel showed characteristic rod end structure. In optical microscopic observations the resin tags (from bonded composite) formed at the cervical area were shorter and less numerous than those formed at the central and incisal enamel surfaces. As the metal retainer wings of resin bonded bridges almost always cover the cervical areas on the lingual surfaces of abutment teeth, these findings are of clinical significance.

There have been no *in-vivo* investigations into the enamel etch patterns achieved on surfaces of teeth used for bonding RBBs. The objectives of this study were to quantitatively describe enamel etch patterns achieved *in-vivo* on the bonding area of RBB abutment teeth.

MATERIALS AND METHODS

Eighteen patients were selected for inclusion in this study. These patients were to be fitted with mandibular resin bonded bridges as part of an ongoing study in Newcastle Dental Hospital comparing resin bonded bridges with removable partial dentures. Patients selected were between the ages of 39 and 81 (mean age 64.8 years), and comprised 9 males and 9 females. Thirty-four bridges were placed, of which, twenty seven were of a cantilever and seven a fixed-fixed design. Double abutments were used for one fixed-fixed and three cantilever bridges. A total of forty-nine abutment teeth were used comprising twelve incisors, twenty canines and seventeen premolars. Study of three of these abutment teeth (two incisors and one canine) was subsequently abandoned due to the presence of artefacts on the lingual surfaces

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rendering them unreadable by the scanning electron microscope.

All abutment teeth had been minimally prepared to produce rest seats, finishing lines and grooves where appropriate. Prior to etching, the teeth were cleaned with pumice and water slurry for fifteen seconds on each tooth with a bristle prophylaxis brush in a dental handpiece. The teeth were then washed for fifteen seconds using a 3-in-1 syringe and high volume aspiration. Isolation was routinely achieved with cotton wool rolls and saliva ejector as the successful placement of rubber dam was rarely possible. Abutment teeth were etched for 30 seconds with 37% phosphoric acid, washed for 30 seconds using water, and then dried with compressed air using the 3-in-1 syringe.

Prior to bridge placement the etched lingual surfaces were recorded using an addition cured silicone impression material, President (Coltene, Kendal House, Victorian Way, Burgess Hill, West Sussex, U.K.). The impression technique used is a modification of that described by Beynon⁹ and described by Hobson *et al*¹⁰ and used for *in vivo* replication of etch patterns by Hobson *et al.*^{11,12}. A putty 'tray' is constructed and then using light body impression material a high resolution impression is taken of the etched surface. The set impressions were removed, carefully washed with water and dried for inspection with a hand (X2) magnifying glass. Any impressions that had obvious defects were discarded and new impressions taken.

Following impressions the surface was cleaned using 50% alcohol, air dried and then the RRB was bonded using the adhesive luting cement used Panavia-Ex, (Kuraray, Japan) as described in the manufacturers' instructions. This removes any residue and prevents any deleterious affects that impression taking may have upon the subsequent bond^{13,14}.

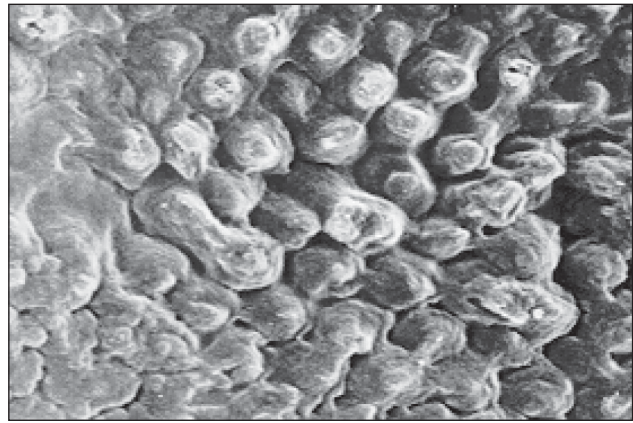
Replica production

The lingual enamel surfaces were individually replicated as described by Beynon⁷ using Spurr's SEM epoxy casting resin (Agar Scientific, Essex, UK). The epoxy replicates were removed from the impressions and mounted on large SEM stubs. They were then desiccated in a warm air oven at 37°C for 24 hours prior to gold sputter coating to a thickness of 15nm. Coated replicates were placed in a Cambridge S240 scanning electron microscope for examination and data collection. In order to maintain a constant magnification across the tooth surface, the microscope was configured to give the greatest possible depth of field. This was achieved by using a long 40mm working distance between the final lens and specimen, with a small 10micron aperture. Examination of the etch pattern was carried out at regular intervals on the entire lingual surface mesiodistally and inciso-cervically where the retainer wing was to be bonded, that is the retainer bonding area (RBA).

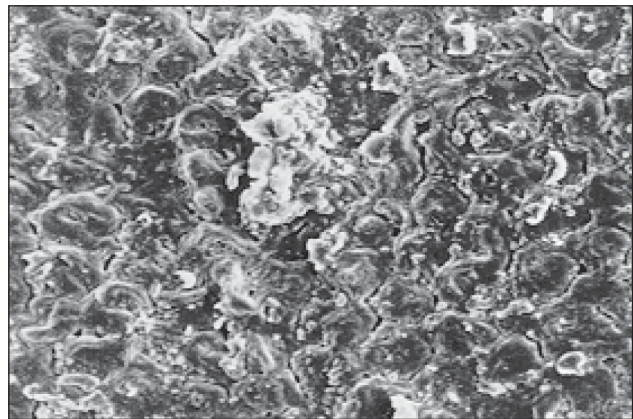
Assessment of etch patterns

Replicate acid etch patterns were described using a modification of the classification of Galil and Wright¹⁵ (Figure 1).

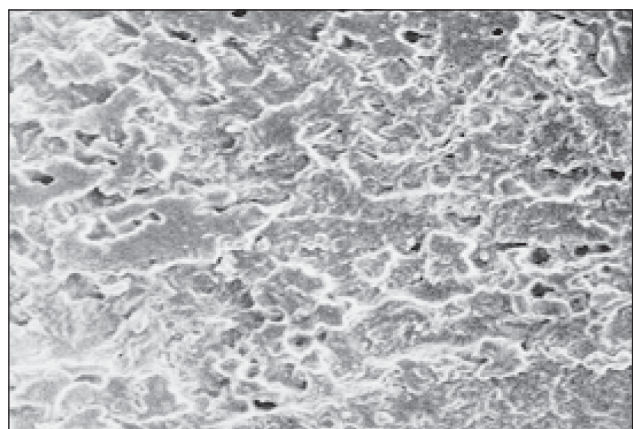
Type 1: ideal etch, corresponding to Galil and Wright types I and II.



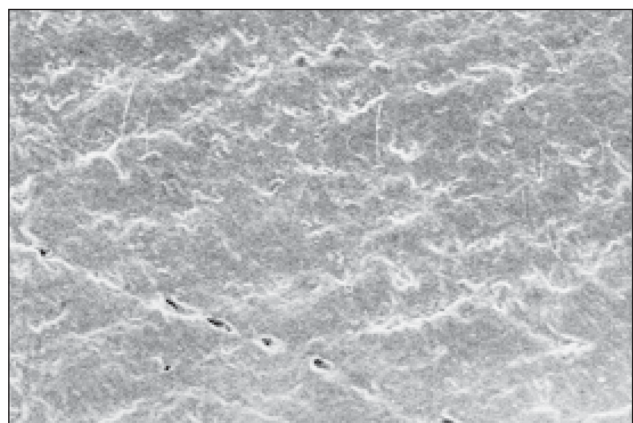
Type 1 - Ideal etch



Type 2 - Etched enamel prisms discernible



Type 3 - Pitted enamel surface



Type 4 - Flat, smooth enamel surface

Figure 1. SEM images of etch types

Table 1. Mean percentages of etch types observed on total, occlusal and cervical halves of the RBA surface for incisors, canines and premolars.

Tooth type	No. of teeth	Etch type 1			Etch type 2			Etch type 3			Etch type 4		
		Total	Occlusal	Cervical	Total	Occlusal	Cervical	Total	Occlusal	Cervical	Total	Occlusal	Cervical
Incisors	10	1.59	1.41	0.08	7.11	3.64	3.48	21.97	12.02	9.95	69.32	32.93	36.39
Canines	17	1.37	0.58	0.84	6.92	3.78	3.10	16.00	9.99	7.01	75.64	35.78	37.82
Premolars	19	1.20	0.69	0.30	9.66	5.77	3.37	19.50	11.88	6.36	69.64	29.45	41.74

Type 2: where etch patterns were discernible, but not the classical ideal etch, corresponding to Galil and Wright type III.

Type 3: showing a pitted enamel surface, corresponding to Galil and Wright type IV.

Type 4: a flat smooth enamel surface with no discernible etch pattern whatsoever, corresponding to Galil and Wright type V.

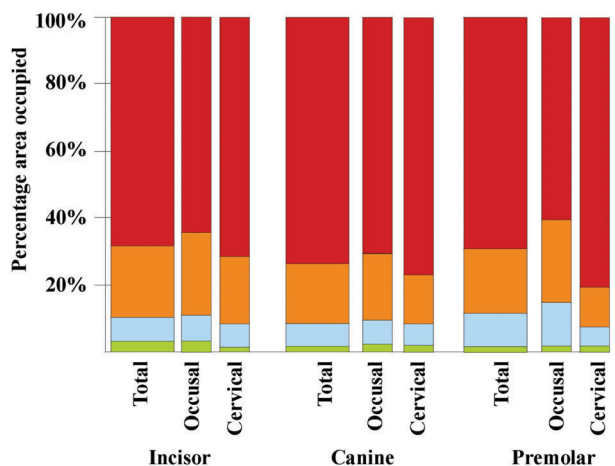
Histometric methods were used in the quantification of the etch pattern patterns. This process involves assessing a specific number of points within a sample to achieve an accurate picture of the whole and makes use of point counting at regular intervals by using a grid placed over the subject and grading the tissue at each intersection. The number of intersections coinciding with a feature is proportional to the area occupied by that feature within the whole sample. Application of this process allowed a more rapid measurement of the area of the RBA occupied by each etch pattern. Reference to earlier work^{10,13,14} suggested that the required number of intersections was 1900 per RBA.

To achieve the observation of 1900 intersections per RBA, the enamel surface was examined at 1050X magnification with the SEM image displayed on a 14 inch, high-resolution monitor. The monitor had a grid superimposed on the screen with 30 intersection points. Grid samples were approximately 90 microns X 70 microns and sampling was taken over the entire lingual surface of the RBA, from mesial wraparound to distal wraparound and from incisal/occlusal to cervical finish line on the preparation. By moving the area of the RBA being viewed in a horizontal and vertical stepwise grid pattern using the vernier controls of the SEM stage, 64 areas of the RBA were examined. This gave a total of 1920 intersections counted per RBA and approximated to sampling every fourth prism.

A single operator (TC) was used throughout the study. Five tooth replicates were randomly selected for an error study to check the reproducibility of the technique. These tooth replicates were assessed histometrically on two occasions at intervals of at least two months apart. A signed rank test was used to examine the data for possible differences between the two measurements. No significant difference was found between the two counts ($p>0.05$)

Data analysis

Data was recorded manually onto proforma data collection sheets, so that the number of intersections for each etch type was recorded for each grid area examined. The column totals were then calculated to give the total number of intersections for each etch type (a) on the incisal/occlusal half of the sample, (b) on the cervical half



Tooth types: total - occlusal and cervical halves

Figure 2. Graph of the incisor, canine and premolar tooth types vs.etch pattern distribution on total, occlusal and cervical halves Retainer Bonding Area

of the sample and (c) on the total surface of the sample. This allowed the calculation of the relative percentage area occupied by each etch type on the RBA of the tooth.

A one-way analysis of variance test was performed to test for significant differences between tooth type (incisors, canines and premolars) and etch patterns observed using the raw data and not the percentage conversions. Differences in the distribution of etch pattern within the RBA of individual tooth types and the relationship between mean etching ratios for abutment teeth of debonded and non debonded bridges were assessed using two-sample t-tests.

RESULTS

The mean percentage areas occupied by each etch pattern on the Retainer Bonding Areas (RBAs) on the lingual surfaces of 46 resin-bonded bridge abutment teeth is provided in *Table 1*. This table allows comparison of the quantity and quality of etch observed on the total RBAs, the occlusal halves, and the cervical halves of the RBAs of the incisor, canine and premolars. A graphical summary of this information is provided in *Figure 2*. It can be seen that relatively large areas of the RBA on all tooth types demonstrated poor or no etch (type 4). This ranged from 69.32% (incisors) to 75.64% (canines). For all tooth types the mean sum total of etch types 1 and 2, which represents what is considered the desired optimal etch pattern, amounted to less than 11%.

There was no statistically significant difference ($p>0.05$) between tooth types (incisor, canine and premolar) and

the quality of etch pattern observed on the total RBA, further analysis combined the tooth types. There was no significant difference between quantity and quality of etch observed between the occlusal and cervical halves of the RBAs on all tooth surfaces for etch types 1 and 2 ($p=0.79$ and $p=0.26$). However, there was a significant difference between the occlusal and cervical halves for the amount of etch types 3 and 4 ($p=0.014$ and $p=0.011$). There being greater amounts of type 3 and less type 4 etch occlusally.

The distribution of etch patterns on total, occlusal and cervical halves of incisor, canine and premolar retainer bonding areas is illustrated in *Figure 2*. The occlusal half of the incisor RBAs had a mean overall etch distribution of 35.1% (being the sum totals of etch types 1, 2 and 3) compared to 26.0% of the cervical half. The remainder of both surfaces was therefore seen to have very poor, or no etch (type 4). 2.8% of the occlusal half had optimal, or type 1 etch, compared to just 0.16% of the cervical half. The occlusal half of the canine RBA was found to have a mean area of etch (type 1,2,3) of 27.44%, with the area of no-etch therefore being 71.56%. The cervical half in comparison had an area with no etch of 76.64%. However, that the area of optimal, type 1, etch was slightly greater in the cervical half, comprising 1.68% compared to 1.16% occlusally. The occlusal half of the premolar RBA was found to have a mean area of no-etch (type 4) of 57.9% with the cervical half having an area of no-etch of 83.48%. The amount of optimal type 1 etch was, again, very small in both halves, with 1.38% on the occlusal compared to 0.6% on the cervical.

DISCUSSION

There have been no previous reports of investigation of etch patterns on the lingual enamel of teeth and no studies have attempted to examine the etch patterns obtained on the areas used for bonded retainers. A limited range of teeth were available for use in this study, all were mandibular teeth comprising incisors¹⁰, canines¹⁹ and premolars¹⁷. It can only be speculated upon whether the inclusion of maxillary teeth and molar teeth would yield different results. Other investigations of the etched tooth surface using the SEM involved similar numbers but included both maxillary and mandibular teeth^{5,14,16}. Most other studies have tended to concentrate on only examining the etch pattern qualitatively, whereas in this study a methodical step by step quantitative analysis of the lingual surface has been performed.

Although one of the inclusion criteria was absence of restorations on the lingual surfaces of the teeth, the age of the study patients that there had been some loss of surface enamel throughout the patient's lifetime and the remaining enamel would be thinner than on a young tooth. In addition, there was some minimal mechanical preparation of the lingual surface of the abutment teeth, to optimise the design of the bonding area was undertaken. This loss of enamel from the tooth surface makes it possible that at times the surface being etched, was in fact dentine. This seems to be substantiated by the presence of visible dentinal tubules on the surfaces of a number of teeth that demonstrated poor or no etch (*Figure 3*).

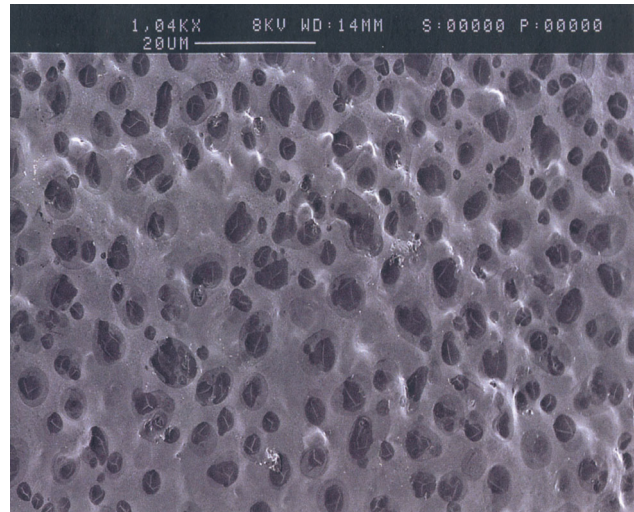


Figure 3. SEM photograph of Dentinal Tubules Seen on RBA (taken from tooth 113 at magnification 1040X)

Shay *et al.*¹⁷, demonstrated that age had no significant effect on tooth solubility in phosphoric acid. The mechanical removal of enamel, through wear and tooth preparation, removes the rodless (prismless) enamel which is distributed more cervically than incisally^{18,19}. Garcia-Godoy and Gwinnett²⁰ compared the etch achieved on deciduous teeth, half of which had the rodless enamel mechanically removed before etching, the other half left intact and etched. They found more uniform and well-defined etch patterns on the mechanically pretreated teeth. That was not the case with the findings in this study as we found that there were large areas of poor etch or no etch. Exposure to fluoride increases the proportion of fluorapatite within the enamel rendering it less soluble to acid etchants²¹. It is conceivable, as the study was based in a fluoridated area, that some teeth were more susceptible to acid etching than others were.

The etch patterns viewed in this investigation were found to be similar to those described in work of Galil and Wright¹⁵ and Brannstrom²². Preferential dissolution of the core and the rod were both seen, as were pitted and smooth areas. Many areas were found to contain well defined etch patterns (types 1 and 2) side by side with areas of no etch whatsoever, which substantiates the findings of Futatsuki²³.

Although Brannstrom *et al.*²² used a quality scale to describe etch patterns in enamel, no quantitative measurements of etch pattern distribution was made by any worker prior to the work of Mattick¹⁴, in her investigation of etch patterns on buccal surfaces prior to orthodontic bonding.

No previous studies have investigated the distribution of etch patterns on the RBA surface of abutment teeth. It appears from this study that the quality and quantity of surface etch does not vary greatly between the different tooth types and that the surface etch, both qualitatively and quantitatively, was found to be surprisingly poor on all tooth surfaces. This is in contrast to the findings of most other workers who examined the buccal surfaces of teeth¹¹. Mattick¹⁴ found significant differences between different tooth types in terms of etch quality and quan-

tity on a defined section of the buccal surface. She also found, however, that the poorer quality of etch was the predominant type¹⁴. Oliver²⁴, on the other hand, found etch types 1 and 2 predominate on the buccal surfaces of premolars and molars²⁴. This is clearly different to the results of this study. The reasons for this are not clear. Lingual enamel is believed to be different to buccal enamel²⁵, although this is a somewhat controversial topic due to paucity of documented research on the histology of lingual enamel. However, the main difference between this investigation and others studies might be explained by the physiological and iatrogenic loss of surface enamel from the lingual surfaces of these teeth. Exposure of deeper subsurface enamel or indeed exposure of dentine could impede the quality of etch obtained.

The results of the analysis found no significant differences in quality and quantity of etch between different tooth types on the whole RBA, the occlusal half of the RBA or the cervical half of the RBA. This allowed the pooling of results from all the teeth when testing for significant differences within individual teeth. There was a trend for a better quality of etch occlusally but no significant difference was found between occlusal and cervical in terms of types 1 and 2 etch. This is not very surprising in view of the small quantities of types 1 and 2 observed. However, there were significant differences found between occlusal and cervical for etch types 3 and 4. Significantly more type 3 etch was found occlusally, and significantly more type 4 etch was found cervically. Galil and Wright¹⁵ found a greater proportion of poor quality etch cervically on the buccal surfaces of teeth. This is similar to the results of this study on lingual tooth surfaces. A possible explanation for this could be, due to enamel being thinner cervically in general, preparation for the RBB especially in placement of a finish line may be sufficient to remove any enamel present, exposing the underlying dentine. Dentine will not etch in the same manner as enamel due to the higher organic content, hence no comparable etch patterns can be seen, however bonding adhesives are available that bond to both enamel and dentine.

CONCLUSIONS

Further research is required into etched lingual surfaces of younger, unprepared teeth. It would be of interest to determine whether tooth preparation does in fact affect the quality and quantity of etch observed on the tooth surface. Also, the relationship between etch pattern, bond strength and bond failure requires investigation. As areas of dentine were found on the lingual surface clinicians should consider using a method that is capable of bonding to both enamel and dentine.

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