Bonding with Self-Etching Primers - Pumice or Pre-Etch? An In Vitro Study

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BONDING WITH SELF-ETCHING PRIMERS – PUMICE OR PRE-ETCH? AN IN VITRO STUDY

by

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ABSTRACT
BONDING WITH SELF-ETCHING PRIMERS – PUMICE OR PRE-ETCH? AN IN VITRO STUDY

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The objective of this study was to compare the shear bond strengths (SBS) of orthodontic brackets bonded with self-etching primer using different enamel surface preparations.

A 2-by-2 factorial study design was used. Sixty human premolars were harvested, cleaned and randomly assigned to four groups (n=15/group). Teeth were bathed in saliva for 48 hours to form a pellicle. Treatments were assigned as follows: Group 1 was pumiced for 10 seconds and pre-etched for five seconds with 37% phosphoric acid before bonding with self-etching primer (Transbond Plus). Group 2 was pumiced for ten seconds before bonding. Group 3 was pre-etched for five seconds before bonding. Group 4 had no mechanical or chemical preparation before bonding. All teeth were stored in distilled water for 24 hours at 37^{o}C before debonding. The SBS values and Adhesive Remnant Index (ARI) score were recorded. Scanning electron microscopy (SEM) was used to investigate the enamel changes at each stage of surface preparation and bonding.

The SBS values (±1 SD) for Groups 1-4 were 22.9±6.1, 16.1±7.3, 36.2 ±8.2, and 13.1±10.1 MPa, respectively. Two-way ANOVA and subsequent contrasts showed statistically significant differences among treatment groups. ARI scores indicated the majority of adhesive remained on the bracket for all 4 groups. SEM micrographs showed variable enamel surface roughness depending upon preparation.

In conclusion**,** pre-etching the bonding surface for five seconds with 37% phosphoric acid, instead of pumicing, when using self-etching primers to bond orthodontic brackets, results in greater shear bond strengths.

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CHAPTER 1

INTRODUCTION

The orthodontic profession is constantly seeking to improve and optimize the technique of bonding brackets to enamel. Self-etching primers (SEP) have been extensively researched[1-15] and have emerged as a successful alternative to the conventional acid-etch bonding technique. Since the introduction of SEPs, it has become accepted that pumicing the bonding surface beforehand to remove the salivary pellicle results in increased bond strength and decreased clinical failure rates[11,15]. A key to successful orthodontic bonding is removal of the salivary pellicle. In the conventional multi-step, acid-etch bonding procedure the pellicle is removed by application of 37% phosphoric acid for 15-60 seconds, therefore pumicing is not necessary[1,16,17]. Although marketed as reducing the number of steps in bonding by combining the conditioning and priming stages, the need for initial pumicing is reintroduced when using SEPs.

Concerns regarding the use of pumice include the time required to individually pumice each tooth and rinse away the paste, the possible introduction of gingival crevicular fluid proteins onto the enamel surface, and the potential for mechanical injury to the gingiva, resulting in bleeding onto the bonding surface. However, elimination of pumicing from the SEP bonding sequence leaves a compromising salivary pellicle on the enamel. An alternative to pumicing to remove the salivary pellicle when using SEPs would be to introduce an etching step. Anecdotal reports suggest a short 5-10 second pre-etch with 37% phosphoric acid can result in a clinically superior performance when compared with pumicing, but no evidence exists in the literature to confirm the clinical effectiveness of the procedure. In vitro studies [18-22] have shown consistently greater bond strengths when enamel was pretreated with phosphoric acid before bonding with SEPs. However, the teeth in these studies were not pumiced when bonding with SEPs.

The authors are not aware of any published studies that compared bond strengths between acid pretreated and pumiced enamel with the use of SEPs. Although some clinicians have adopted a pre-etch step in place of pumicing in their SEP bonding protocols, conclusive in vitro and in vivo studies examining this practice are needed. The aim of this in vitro study was to investigate SBS values of brackets bonded with an SEP to salivary pellicle-coated human teeth that were pretreated with pumice and/or 37% phosphoric acid, or not pretreated at all.

CHAPTER II

LITERATURE REVIEW

In vivo studies concerning pumicing, bonding and self-etching primers:

Barry[1], in 1995, made a clinical investigation on the effects of pumice prophylaxis omission on band and bond failure. He pumiced half of his sample (614), and did not pumice the other half. Using conventional acid-etch bonding at 15 and 60 seconds, he found no statistical difference on bond failure rates.

Asgari et al[4], in 2002, clinically compared the failure rates of traditional acid etching versus a new self-etching primer. One hundred and seventy four teeth were bonded using each method. All the teeth were pumiced before bonding. The results after 6 months showed better bracket retention using the self-etching primers (0.57% failure vs 4.6%).

Ireland et al[5], in 2003, also investigated, in vivo, the bond failure rates with a new self-etching primer system. Twenty patients had half their teeth bonded using a self-etching primer (Transbond Plus SEP) and the other half using conventional etching. No teeth were pumiced. After six months, failure rates for the SEP brackets were 10.99% versus 4.95% for those bonded using conventional etching.

Aljubouri et al[6], in 2004, in a follow up to a 2003 in vitro study, conducted a randomized clinical trial with 51 patients. The performance of a self-etching primer versus two-stage etch and prime for orthodontic bonding was evaluated after six and twelve months. All teeth were pumiced before bonding regardless of bonding technique. The overall bond failure rate between the two techniques was not significant at six or twelve months.

Pandis and Eliades[10], in 2005, presented a comparative in vivo assessment of the long-term failure rate of two self-etching primers. Twenty two patients were used in the study. A split mouth design was used (half the teeth were bonded with one product, Transbond Plus SEP, and the other half were treated with the other product, One Step SEP). All of the teeth were pumiced. Their results showed Transbond Plus had a much lower failure rate (0.94% of brackets failed) versus (8.10%) One Step. However, the adhesive paste used in this study was Transbond XT, suggesting a possible sensitivity between manufacturers' products.

Burgess et al[11], in 2006, studied in a randomized clinical trial, the need for prophylactic pumicing using self-etching primers. This study was cut short as a result of excessively high failure rates using First Step SEP. A split mouth design was used, pumicing half and not pumicing the other half of the mouth. Failure rates of 32.2% (pumiced) versus 55.6% (not pumiced) were recorded. They concluded that pumicing has a significant effect on failure rates, but this material cannot be recommended for clinical use.

Lill et al[15], in 2008, studied the importance of pumice prophylaxis for bonding with self-etching primer. The results were significantly better than those recorded by Burgess et al (2006). Thirty patients were selected using the split mouth technique (only half of the mouth pumiced). Transbond Plus SEP was used with adhesive pre-coated brackets. The results showed failure rates of 2.4% with pumiced teeth versus 11.4% with non pumiced teeth.

Ireland et al[17], in 2002, studied the effect of pumicing using resin modified glass poly (alkenoate) cement and a conventional no-mix composite for bonding orthodontic brackets. The conventional acid-etch bonding system was used. They found that pumicing before bonding had no effect on failure rate over the 18 month experimental period.

In vitro studies:

Bishara et al[2], in 2001, observed the effect of a self-etching primer/adhesive on the shear bond strength of orthodontic brackets. Forty-five freshly extracted human molars were collected and stored in a solution of 0.1% thymol. No attempt was made to recreate oral environment conditions. The teeth were cleansed and polished with pumice and rubber prophylactic cups for 10 seconds. Twenty-five teeth were etched with 37% phosphoric acid followed by a sealant and then light cured. The remaining twenty teeth were bonded using the self-etching primer Prompt L-Pop (ESPE Dental AG). Shear bond strengths were measured and showed lower values for the self-etching primers, but were still deemed to be clinically acceptable (7.1 MPa vs 10.4 MPa).

Buyukuyilmaz et al[7], in 2003, studied the effect of self-etching primers on bond strength to find out if they were reliable. They compared shear bond strengths of three different self-etching primers (Clearfil SE Bond, Etch & Prime 3.0, and Transbond Plus) against conventional 37% phosphoric acid etching. Eighty human teeth (4 groups, one control and 3 SEPs) were collected and stored in distilled water after extraction. The water was changed weekly to avoid bacterial growth. The teeth were pumiced, washed and dried before surface preparation. They found that shear bond strength of the Transbond Plus was greater than that of the control group. The other 2 SEPs are used in restorative dentistry and performed poorly.

Rajagopal et al[8], in 2004, made an "in vitro" comparison, using saliva, of shear bond strength and debonding characteristics of conventional, moisture-insensitive, and self-etching primers. One hundred and twenty human premolars were used. They were stored in a solution of thymol 0.1% (wt/vol) to prevent dehydration and bacterial growth. All groups were pumiced before bonding. Of the six groups, three were contaminated with saliva after bonding preparation. They were bonded with the author's saliva on the enamel surface. They found that self-etching primer displayed considerably superior performance under dry conditions compared with contaminated conditions.

Cehreli et al[9], in 2005, analyzed the effect of self-etching primer and adhesive formulations on the shear bond strength of orthodontic brackets in forty-two mandibular bovine incisors. All teeth were cleaned of debris and soft tissue remnants immediately after harvesting. The teeth were then pumiced for 10 seconds. Results showed acceptable bond strengths for the control (acid-etch bond)(10.5 MPa), but all other groups using SEPs showed very poor strengths (~1.7 MPa). However, all teeth were subjected to thermal cycling and water storage following bonding.

Lindauer et al[16], in 1997, studied the effect of pumice prophylaxis on the bond strength of orthodontic brackets using three different methods. Forty-five extracted human teeth where stored in saline solution and included acid-etch bonding. Twenty-four teeth were pumiced before bonding stainless steel brackets using 37% phosphoric acid, and 21 were not pumiced. No attempt was made to recreate the oral environment. The first method measured shear bond strengths and found no significant differences with or without pumicing. The second method used a scanning electron microscope to observe characteristics of the enamel surface after etching with and without prior pumicing. Some differences were noted in localized areas of the enamel, but nothing that affected the bond strengths or failure rates. The third method studied the clinical failure rate of brackets bonded with pumicing (6.6%) and without pumicing (7.4%), and no significant differences were found. Of the 1354 brackets bonded, 95 failed over the two year period. This number does not reflect repeated failures on the same tooth. The authors concluded that pumicing enamel prior to acid-etch bonding does not provide significantly better bond strengths or lower bracket failure rates.

Luhrs et al[18], in 2008, measured the shear bond strength of self-etching adhesives to enamel with additional phosphoric acid etching. Seventy human molars were divided randomly into three groups. Three self-etching products were tested. Half the teeth in each group were pretreated with phosphoric acid. Statistically, one way ANOVA and the two sided Dunnett Test were used. The additional use of phosphoric acid significantly increased the shear bond strength of all the examined self-adhesives. The author recommends considering pre-etching when using self-etching primers.

Rotta et al[19], in 2007, investigated the effects of phosphoric acid pretreatment on the bonding effectiveness of self-etching systems to enamel using scanning electron microscopy. They examined unconditioned and phosphoric acid-conditioned enamel using three self-etching primers. Thirty human molars were used. All self-etching primers applied after phosphoric acid pretreatment exhibited a more retentive etching pattern.

Torii et al[20], in 2002, investigated the effect of acid etching prior to self-etching primer application on the adhesion of resin composite to enamel and dentin. They used bovine teeth. Tensile bond strengths were recorded and shown to be significantly greater in the pre-etched enamel groups.

Erhardt et al[21], in 2004, investigated the influence of phosphoric acid pretreatment on self-etching bond strengths. Forty-eight extracted human third molar teeth were prepared and mounted, embedded in polystyrene resin. Half of the teeth were exposed to acid-etch pre-treatment. The pre-etched teeth were exposed to 37% phosphoric acid for fifteen seconds, rinsed and dried with an air stream. Self-etching primers were applied according to the manufacturers instructions. All teeth were stored in humidity for 7 days at 37 degrees Celsius. The pretreated teeth showed significantly higher shear bond strengths than the untreated teeth (24.6 MPa vs 19.2 MPa).

Miguez et al[22], in 2003, looked at the effect of acid-etching on the enamel bond of two self-etching systems. Sixteen bovine incisors were used. Prior etching was shown to produce higher bond strengths than in the groups that had self-priming only.

CHAPTER III

MATERIALS AND METHODS

Tooth Collection

The study was approved by the Institutional Review Board at Marquette University, approval number HR-1767. Freshly extracted human premolars were washed in running water with all blood and tissue removed, placed in distilled water, and stored at room temperature. The distilled water was changed weekly to avoid bacterial overgrowth. Teeth chosen for the study were free of cracks, caries, and restorations.

A 2-by-2 factorial study design was used. Presence or absence of pumicing (P±) and pre-etching (E±) were the investigated effects, resulting in four treatment sequences, i.e., Group 1 P+/E+, Group 2 P+/E-, Group 3 P-/E+, and Group 4 P-/E- (Table 1). Group 2 follows the manufacturer recommendations for bonding with SEPs and thus can be considered a control group. Sixty teeth were selected and randomly assigned to treatments in blocks of four. The roots of all premolars were then removed with a high-speed diamond bur to aid in the subsequent steps. All teeth were vigorously scrubbed on their bonding surfaces with a toothbrush and running water to ensure a clean surface. No toothpaste or detergent was used. Whole saliva was collected from the author in a glass beaker. Cleaned teeth were immersed in saliva for 48 hours at $37^{o}C$ on a shaking platform to form a pellicle on the enamel surfaces. Immediately before bonding, each tooth was individually removed from the saliva with tweezers and dried with oil-free, compressed air until the surface appeared dry.

Table 1. Experimental Groups

Variable	Group 1	Group 2	Group 3	Group 4
Pumice (P)	Yes	Yes	No	No
Pre-etch (E)	Yes	No	Yes	No

Experimental Group Preparation and Bonding

The teeth allocated to P+/E+ were prepared by pumicing each tooth for ten seconds with a rubber prophylactic cup and fluoride-free pumice (Whip-Mix Corp, Louisville, KY), rinsing with distilled water, and drying with oil-free, compressed air. According to the manufacturer the pumice was composed of 100% silica (Diamataceous earth) but may contain up to 44% crystalline silica (Crisobalite <40%, Quartz <4%). Phosphoric acid (37%) gel (3M Unitek, Monrovia, CA) was placed on the bonding surface of each tooth for five seconds, and the tooth was again rinsed and dried. Bonding orthodontic brackets was executed as per the manufacturer's instruction. Transbond Plus self-etching primer (3M Unitek) was applied to the surface of each tooth and rubbed for five seconds. Next, the bonding surface received a gentle, five second air burst to thin the primer. Adhesive pre-coated, stainless steel premolar brackets (APC Victory, 3M Unitek) with a 10 mm^2 base were placed on each tooth. The excess adhesive was removed with a fine probe. Each specimen was light cured (Ortholux LED Curing Light, 3M Unitek) for ten seconds from the mesial and ten seconds from the distal with the light curing unit perpendicular to the bonding surface.

The other teeth were treated using protocols that included the following modifications: Teeth allocated to P+/E- were not pre-etched. Teeth allocated to P-/E+ were not pumiced, and teeth allocated to P-/E- were neither pumiced nor pre-etched.

Figure 1. Instruments and Materials

Debonding and Classification of Adhesive Remnant Index (ARI)

Following bonding the brackets, each tooth was individually mounted in a cylinder of cold-cure acrylic resin (Great Lakes Orthodontics, Tonawanda, NY) and stored in distilled water for twenty-four hours at 37^0C (ISO/TS 11405)[23]. Each mounted tooth was then placed in a universal testing machine (Instron Corporation, Canton, MA) with the bracket/tooth interface placed parallel to the blade motion. The brackets were debonded using a crosshead speed of 0.1 mm/min with the loading blade contacting between the tie wing and the bracket base as close to the base as possible. The maximum load was recorded and converted to shear bond strength in MPa. After debonding, each tooth and debonded bracket was viewed under an optical stereomicroscope at 10x magnification. The Adhesive Remnant Index (ARI)[24] score was recorded to determine where the bond failure occurred. Possible ARI scores are: 0 for no adhesive left on the tooth, 1 for less than half of the adhesive left on the tooth, 2 for more than half of the adhesive left on the tooth, and 3 for all of the adhesive left on the tooth. Debonding resulting in a fractured crown did not receive an ARI score and was recorded separately.

Figure 2. Pouring Acrylic Base

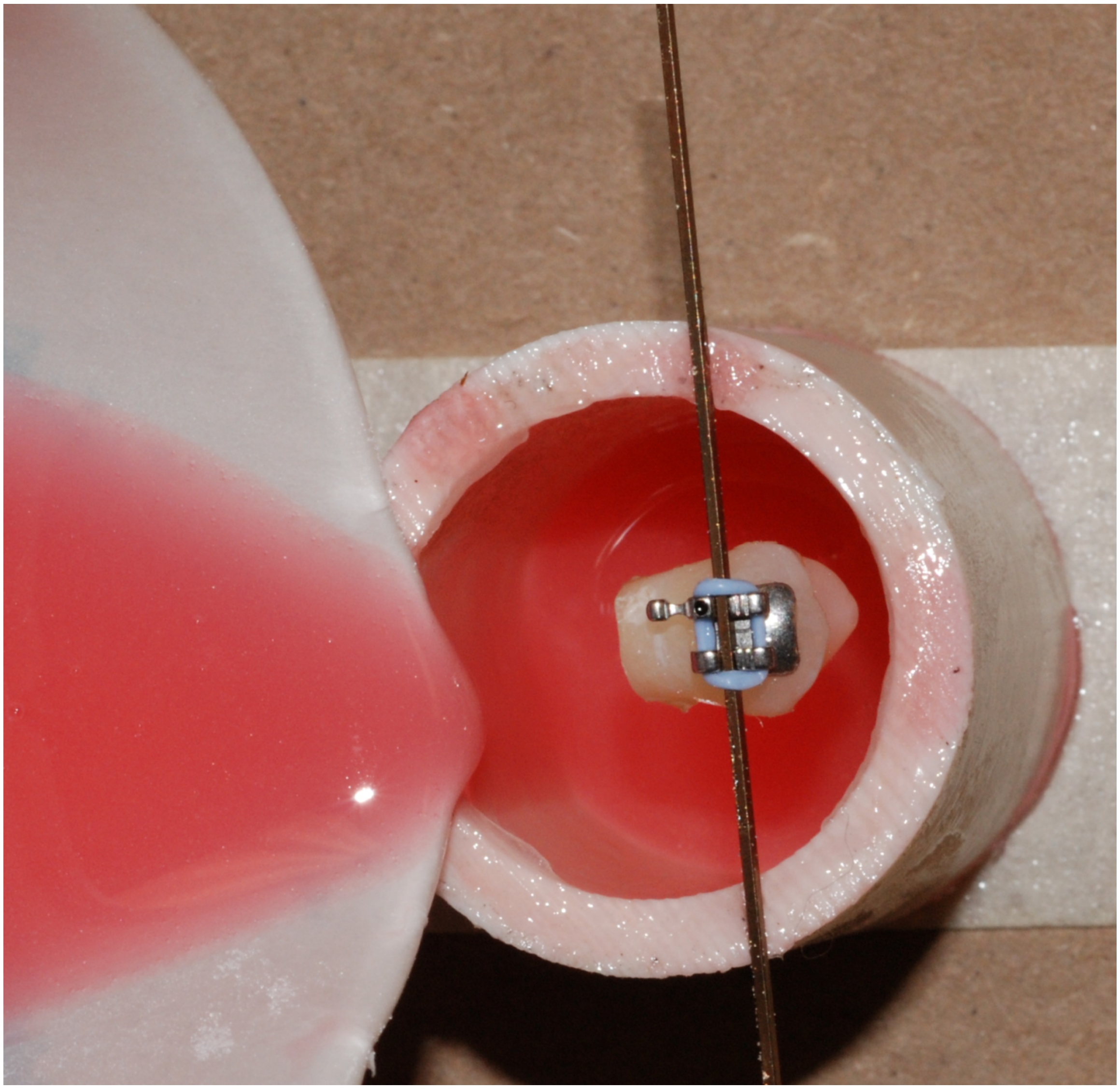


Figure 3. Acrylic Base Set

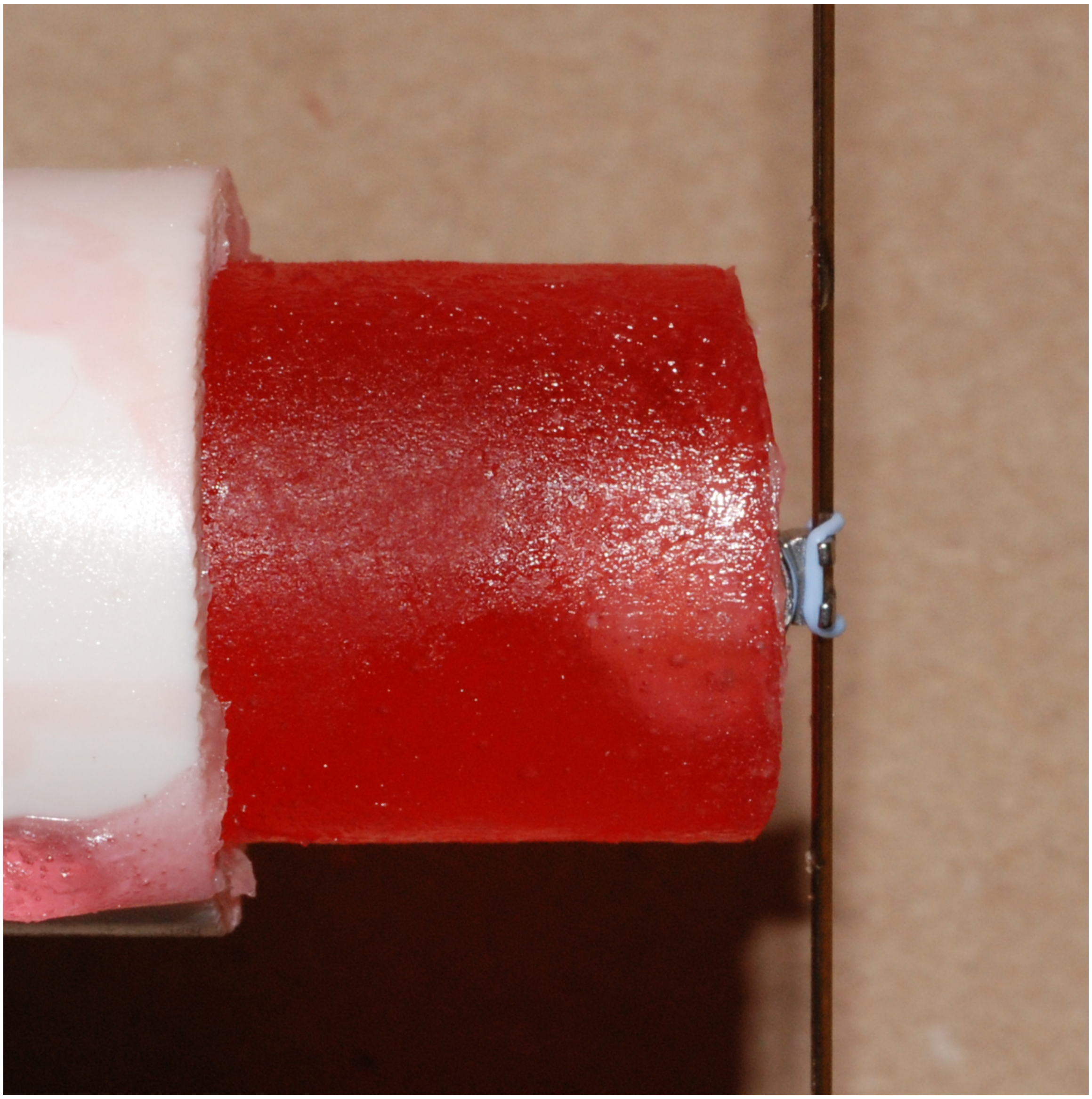
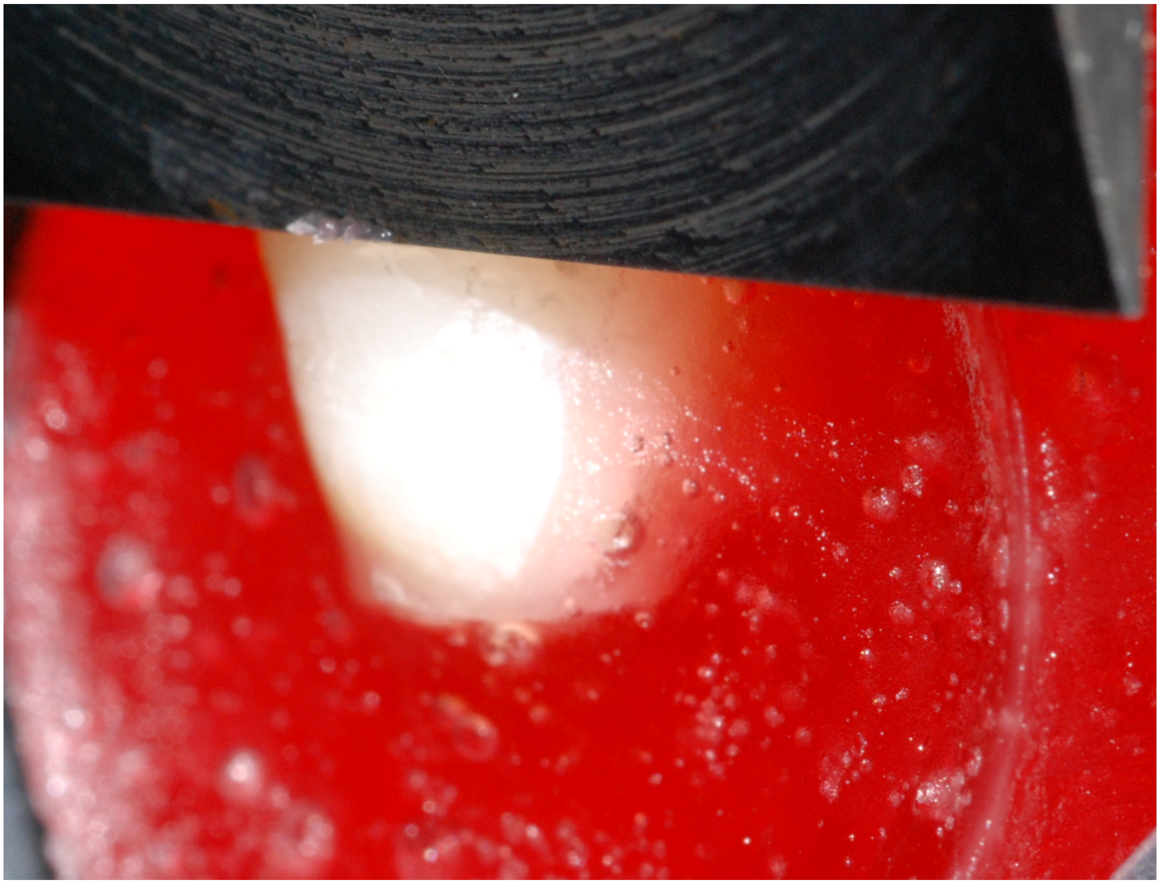


Figure 4. Tooth Mounted in Instron Universal Testing Machine

Figure 5. Bracket debonded in Instron Universal Testing Machine



Scanning Electron Microscopy (SEM)

SEM (JSM-35, Jeol Ltd, Tokyo, Japan) at an acceleration voltage of 25 kV was used to inspect the different stages of the bonding process and to determine the effects each stage had on the enamel. For this purpose, seven additional teeth were prepared according to protocol. SEM micrographs of treated teeth were collected on sputter-coated (gold-palladium) cross-sectional and buccal surface views. For each tooth to be viewed in cross-section, an adjacent area of the tooth was sealed with nail varnish prior to enamel surface treatment to allow a comparative view of untreated and treated areas.

Statistical Analysis

For SBS data, means and standard deviations were calculated and ARI score frequencies were tabulated for each preparation factor combination. Shear bond strengths were analyzed using a two-way analysis of variance with ‘pumicing’ and ‘pre-etching’ as main factors. Contrasts were analyzed to investigate comparisons of interest. Differences were considered to be statistically significant at $p \leq .05$. A Weibull analysis was performed to determine the Weibull modulus, characteristic strength, and bond strengths at specific reliabilities. The statistical significance of differences among ARI score frequencies were examined with a Kruskal-Wallis test and followed up with a Mann Whitney test. SPSS Statistics 17.0 software (SPSS Inc., Chicago, Il) was used for statistical computations.

CHAPTER IV

RESULTS

Detailed results of SBS measurements and their derivatives are presented in Table 2. Statistically significant effects were observed for both main factors as well as for their interaction. For that reason, the statistical analysis was continued on specific contrasts comparing various combinations of presence and absence of both factors. As expected, the absence of any surface preparation (P-/E-) resulted in the lowest SBS values. In contrast, pre-etching alone (P-/E+) was the most effective preparation step. It was statistically different from P-/E- ($p<.0001$), P+/E- ($p<.0001$), and P+/E+ ($p<.0001$). The combination of pumicing and pre-etching was more effective than P-/E- ($p=.003$). There was no statistical difference between P+/E+ and P+/E-. The Weibull analysis (Table 2, Figure 6) shows P-/E+ presented with the greatest Weibull modulus, characteristic strength and bond strengths at 10% and 90% probability of failure, while P-/E- was the lowest in each.

The ARI scores are presented in Table 3. Eighty-five percent of the scores were either 0 or 1, indicating that after debonding most adhesive remained on the bracket. The group without surface preparation (P-/E-) had the greatest frequency of 0 ARI scores and was significantly different ($p<.05$) from the other groups. Six instances of enamel fractures were indentified of which four were found in P+/E+ and two in P-/E+.

SEM micrographs illustrating the effects of the various surface preparations are displayed in Figures 7-14. Untreated teeth exhibited a surface layer of organic material indicative of a pellicle (Figure 7), whereas pumicing produced a relatively clean surface with scratches (Figure 8). The effect of pre-etching is displayed in a buccal view of the teeth (Figure 9) and in a cross-sectional view (Figure 10). The buccal view shows a slight type 1 etching pattern, while the cross-section in Figure 10 shows roughness on the order of several microns. When the tooth was pumiced prior to pre-etching, the roughness in cross-section was of similar depth (not shown). Self-etching primer showed the ability to create a rough surface (Figure 11), although not quite as effectively as pre-etching. However, this ability was relatively limited when the tooth was not pumiced (Figure 12). Pre-etching followed by the self-etching primer appeared to affect the depth of enamel etch (Figure 13) compared with just the pre-etch or self-etch individually. When pumicing was introduced, the roughness appeared to be less pronounced (Figure 14).

Table 2. Shear Bond Strengths and Weibull Analysis Results

Group	Mean ± Standard Deviation (MPa)	Weibull Modulus (b)	Characteristic Strength (a)	Shear Bond Strength (MPa) at 10% Probability of Failure	Shear Bond Strength (MPa) at 90% Probability of Failure
1	22.9 ± 6.1[b]	3.6	25.1	13.5	31.6
2	16.1 ± 7.3[bc]	1.9	18.7	5.8	28.8
3	36.2 ± 8.2[a]	6.5	39.6	28.0	45.0
4	13.1 ± 10.0[c]	1.3	14.3	2.6	27.1

Different letters denote significant differences exist. $P<.05$.

Table 3. Adhesive Remnant Index (ARI) Scores by Group

Group*	ARI Scores				EF**
	0	**1**	**2**	**3**	
1	4	5	2	0	4
2	4	11	0	0	0
3	4	8	0	1	2
4	11	4	0	0	0

*Group 4 had a significantly lower ARI score than other groups

**EF = enamel fracture

Figure 6. Shear Bond Strength and Probability of Failure (%)

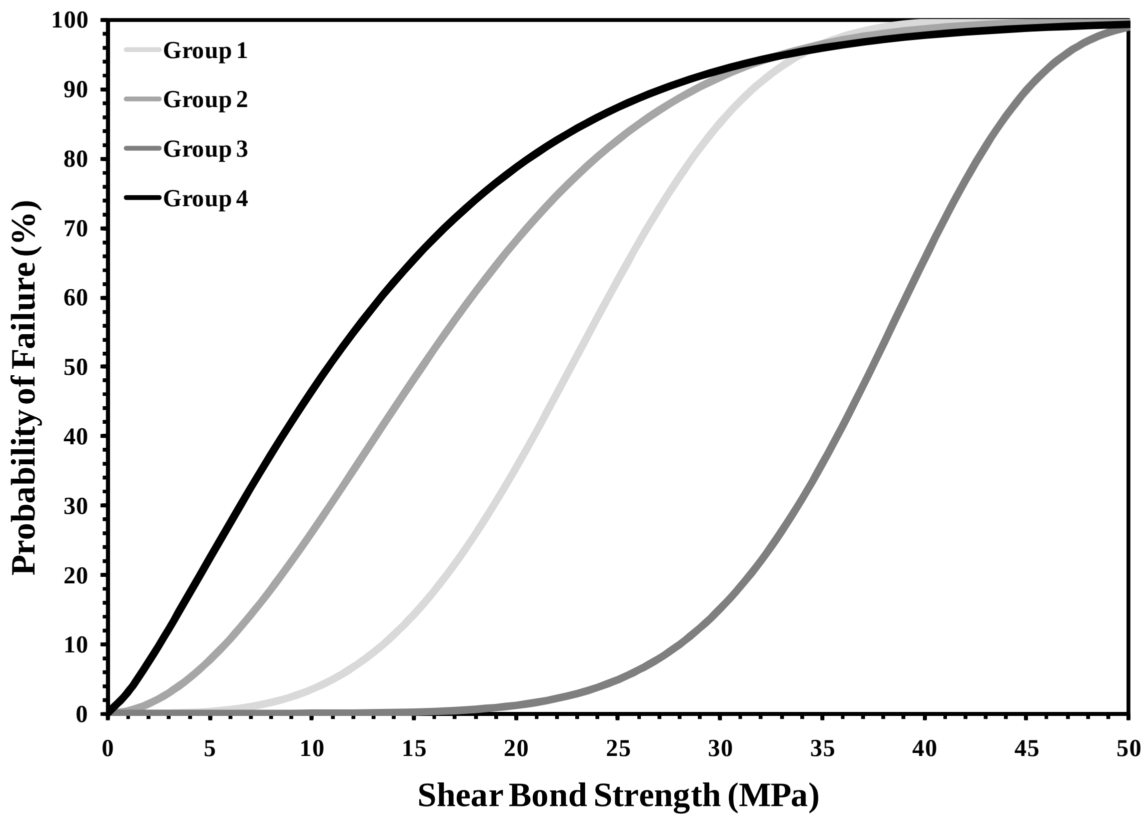


Figure 7. Buccal Surface of Untreated Tooth (Scanning Electron Microscopy)

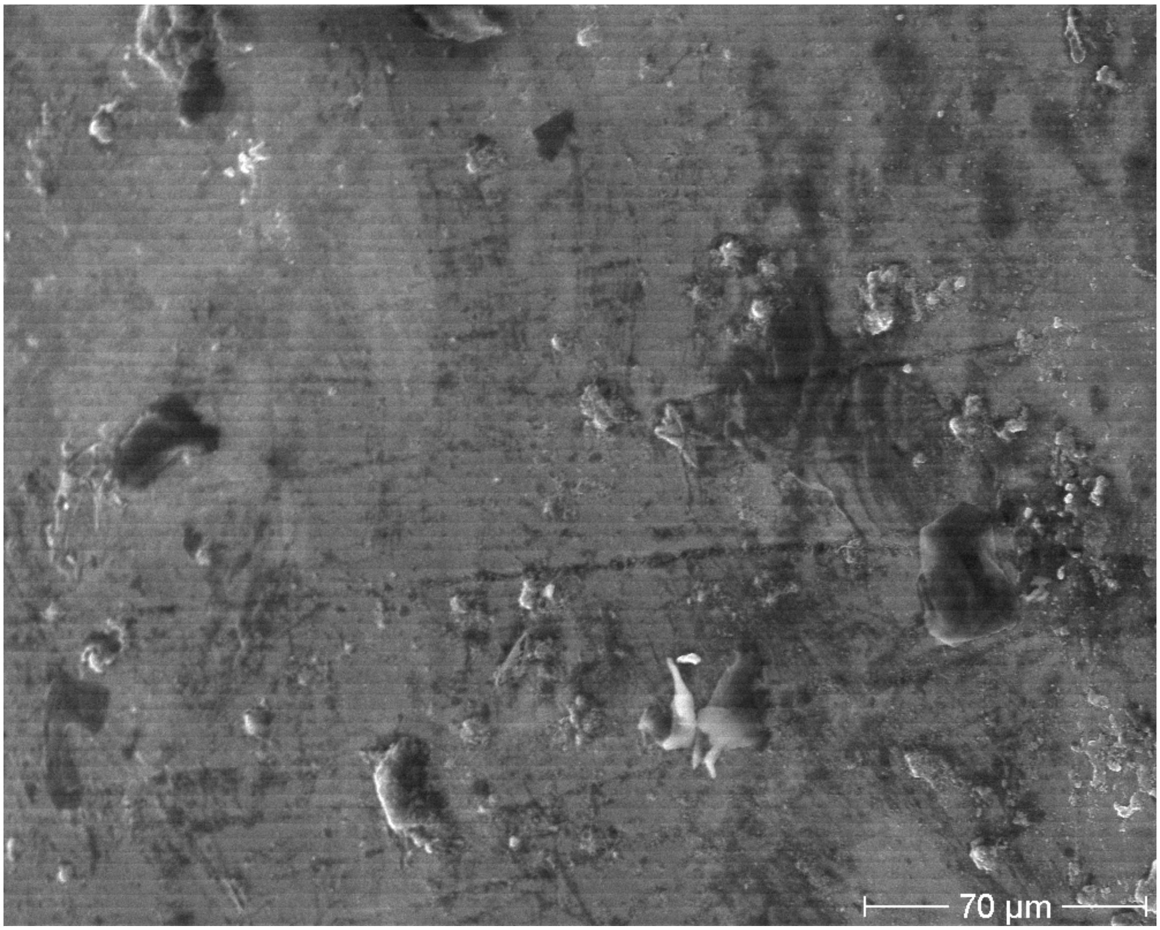


Figure 8. Buccal Surface of Pumiced Tooth (Scanning Electron Microscop**y)**

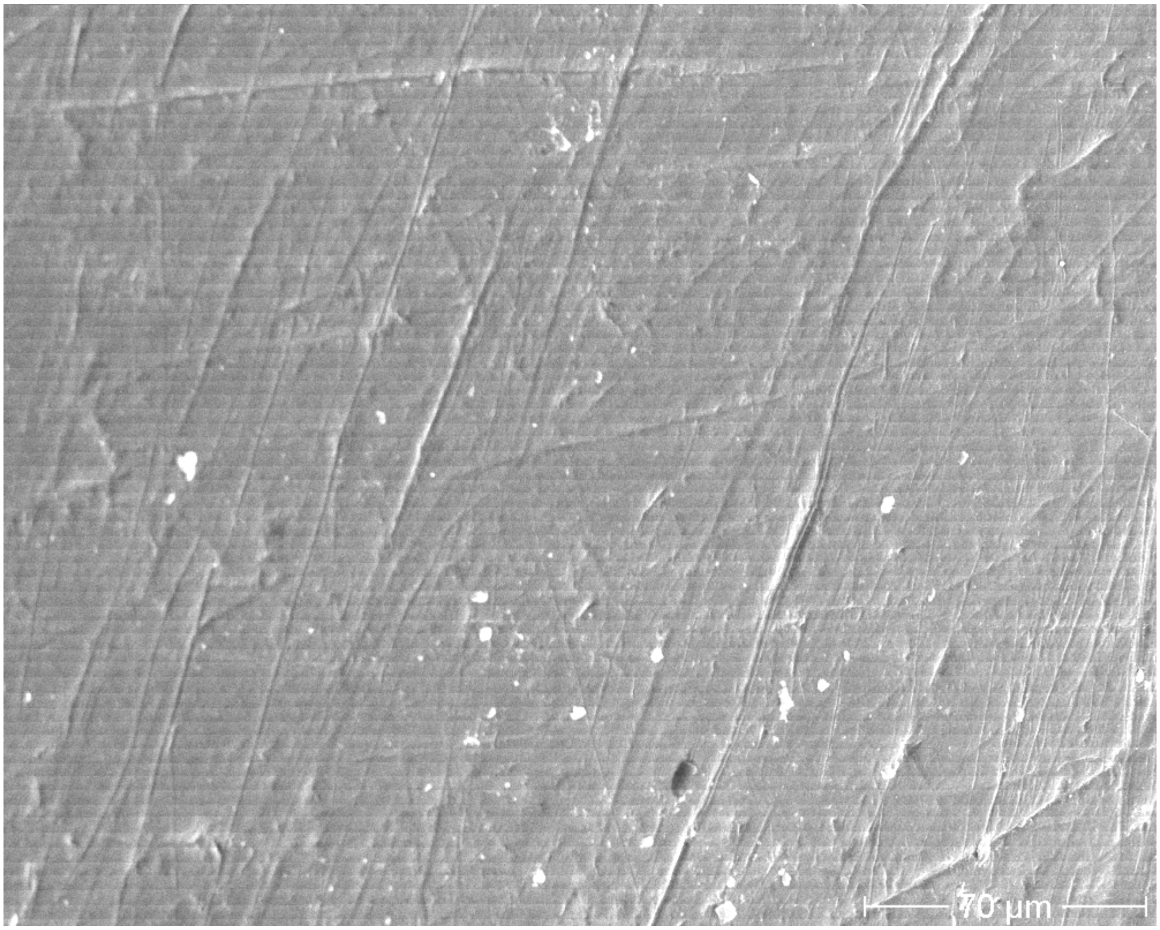


Figure 9. Buccal Surface of Pre-etched Tooth (Scanning Electron Microscopy)

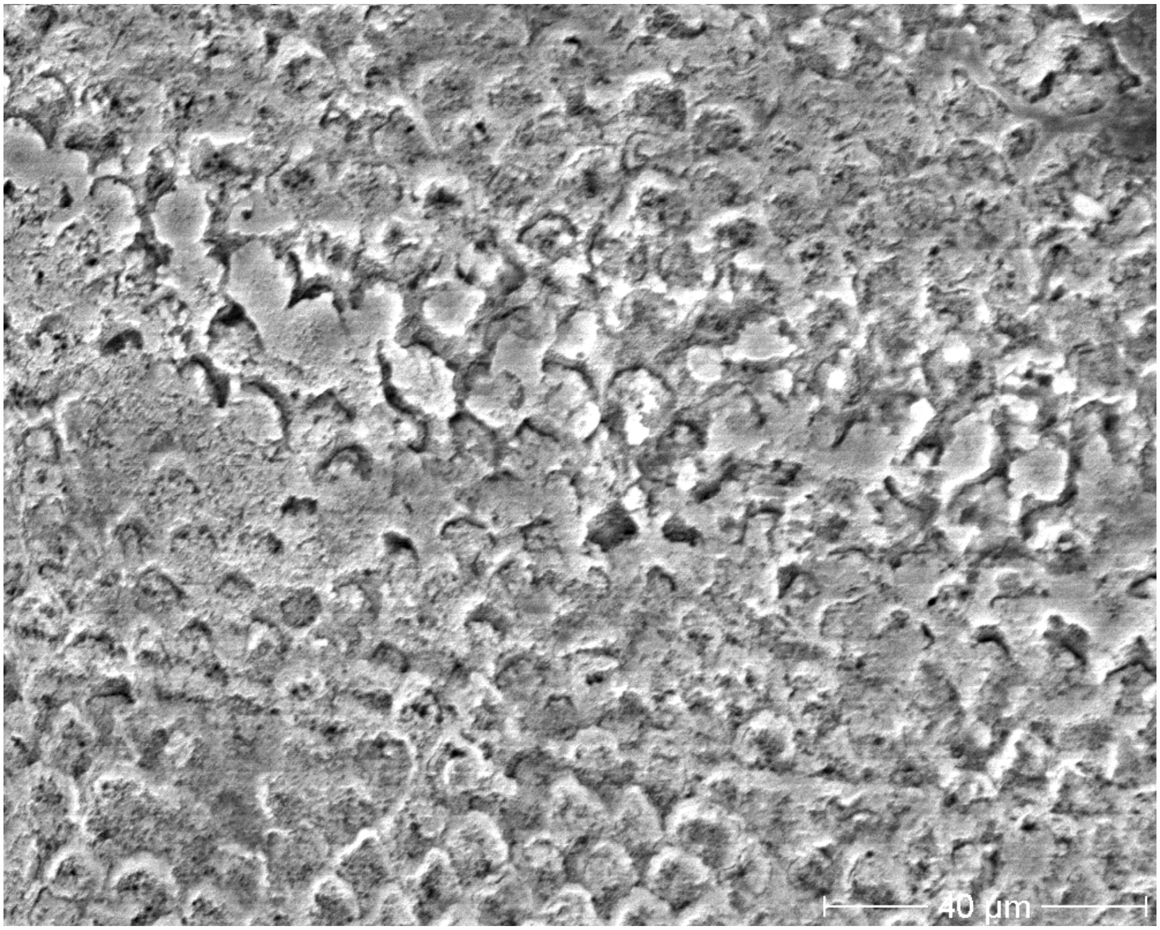


Figure 10. Cross-section of Pre-etched Tooth (Scanning Electron Microscopy)

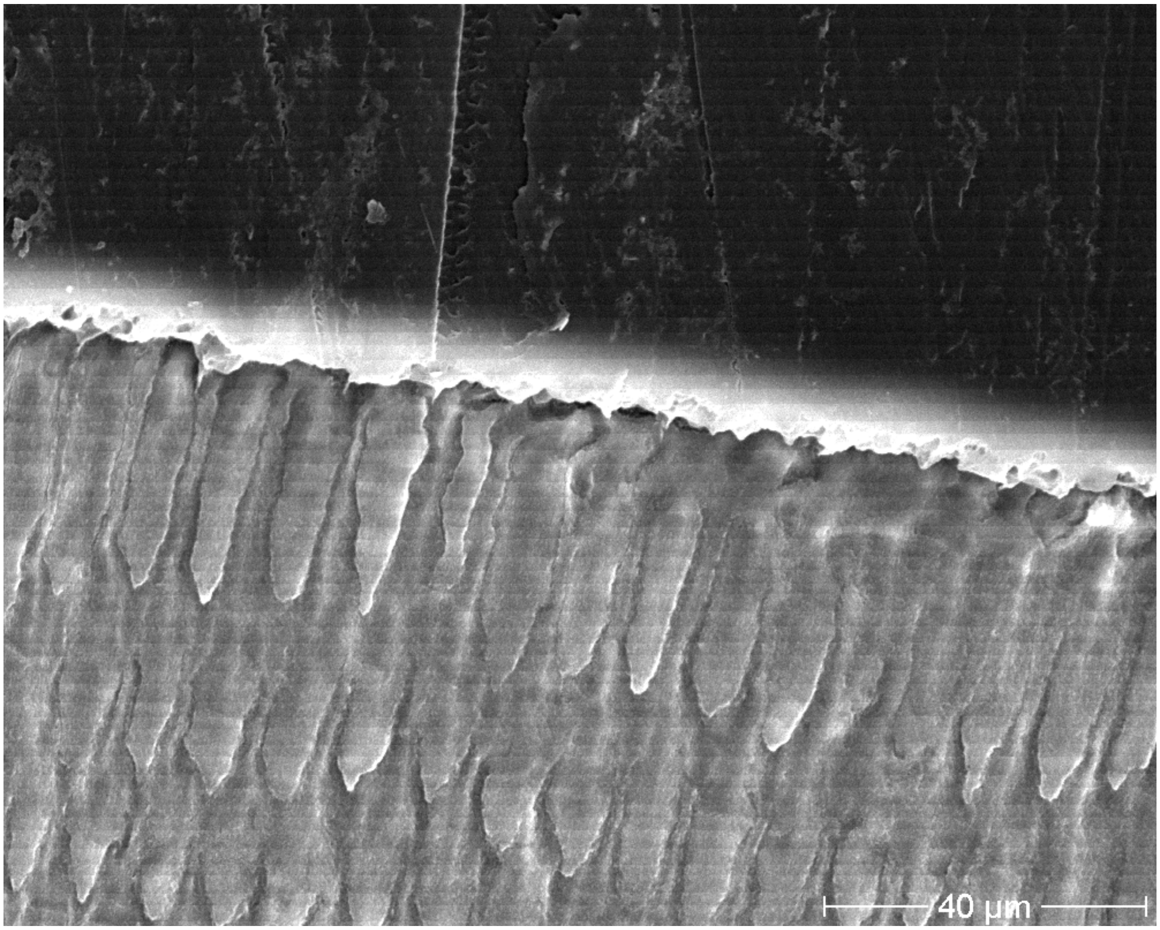


Figure 11. Cross-section after Pumicing and SEP (Scanning Electron Microscopy)

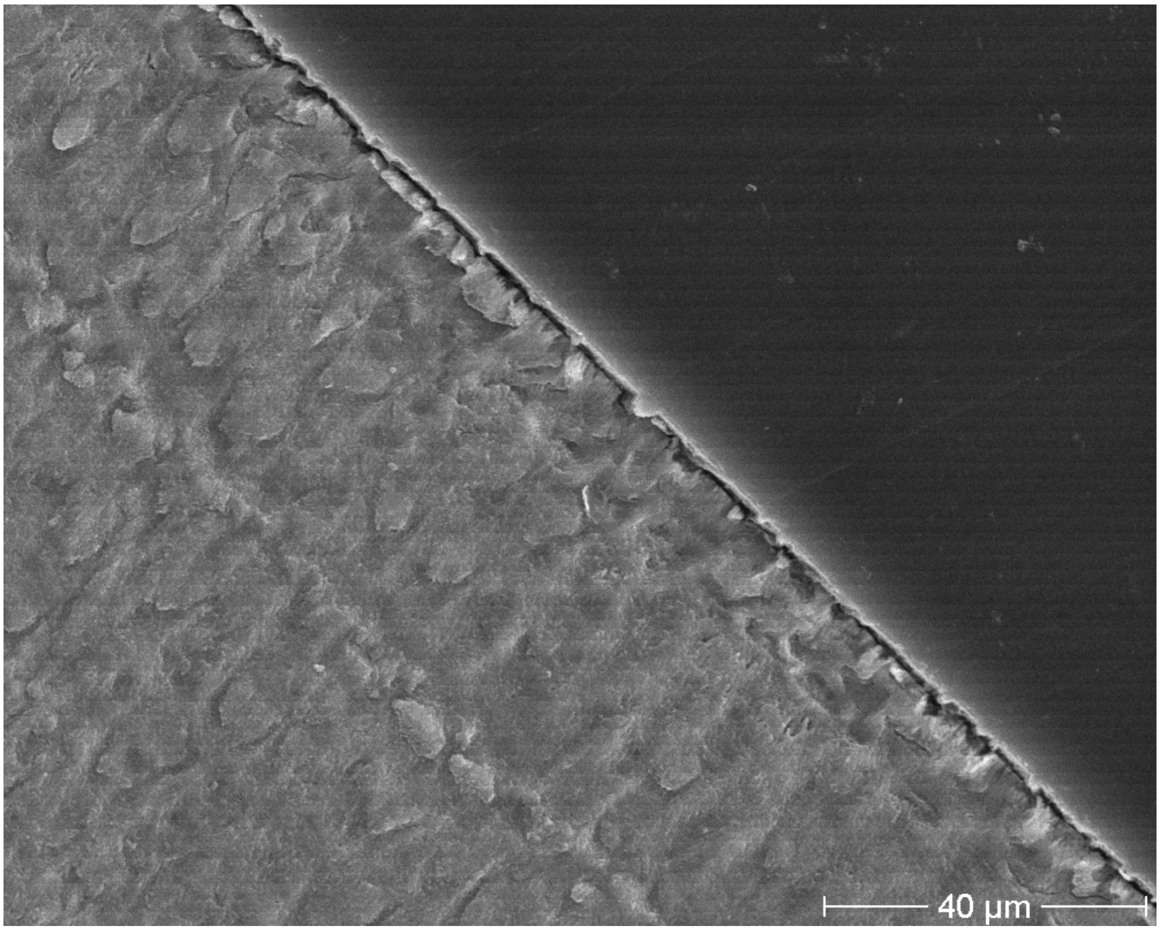


Figure 12. Cross-section after SEP (Scanning Electron Microscopy)

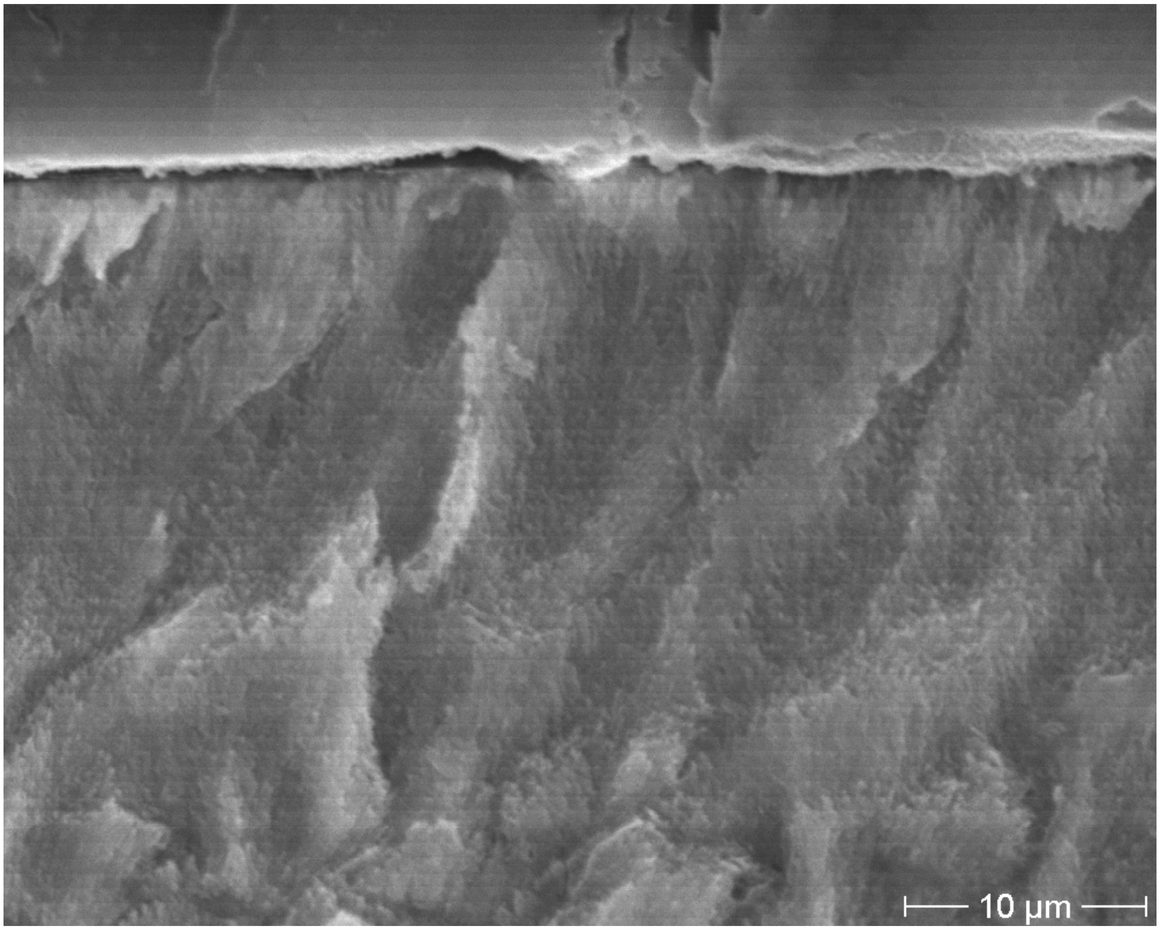


Figure 13. Cross-section after Pre-etching and SEP (Scanning Electron Microscopy)

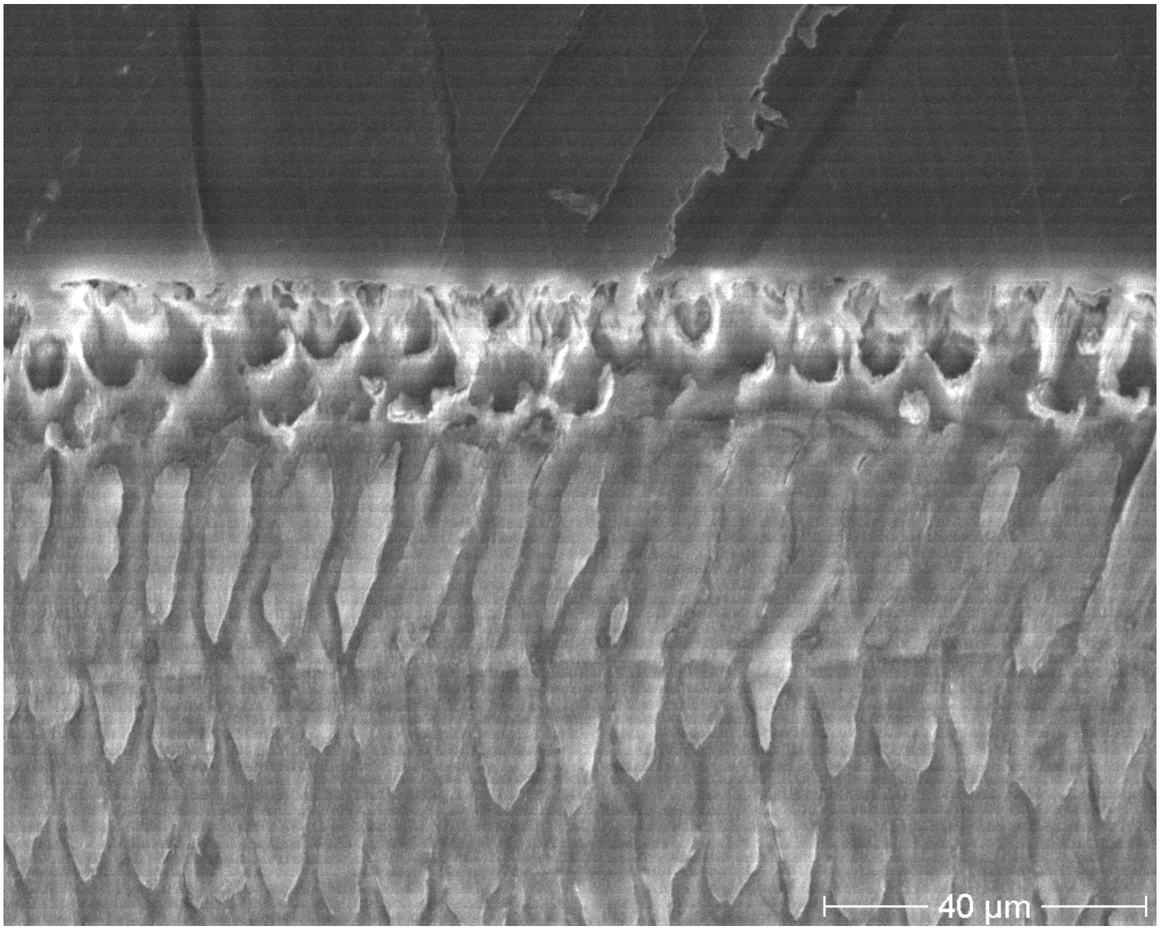
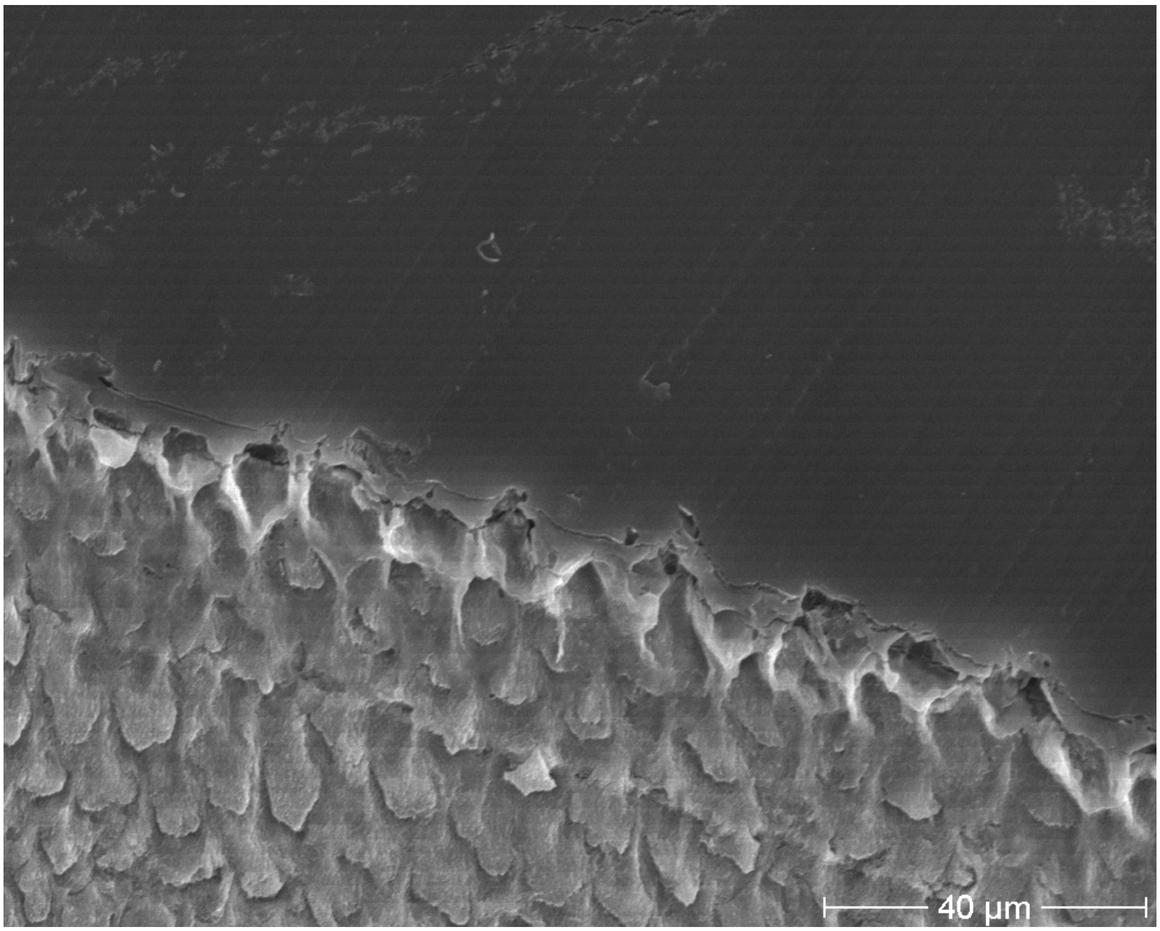


Figure 14. Cross-section after Pumicing, Pre-etching and SEP (Scanning Electron Microscopy)



CHAPTER V

DISCUSSION

The effects of two types of enamel surface preparations, pumicing and pre-etching, on the shear bond strength induced by a self-etching primer were evaluated in this study. Significantly greater SBS values were found when pre-etching preceded SEP application. The effect of pumicing alone was small (and not statistically significant). Furthermore, combined with pre-etching, pumicing reduced SBS values significantly when compared to pre-etching alone. Pre-etching when using SEPs produced greater mean bond strengths compared to that of the manufacturer's recommendation of pumicing followed by SEP application. It should be noted the SBS values for P-/E+ were very high, although they are similar to values found in a few other orthodontic bonding studies.[25,26] While commonly performed, comparison of bond strength values across studies is problematic due to differences in methodological and testing parameters. Therefore, intra-study group comparisons are most valid. With this in mind, based upon this in vitro bonding study, pre-etching has been shown to be a possible alternative to pumicing when using SEPs.

Considering that the P+/E+ group was pumiced and pre-etched before bonding with the SEP, it could have been expected to have the greatest bond strengths or values similar to P-/E+ (the other pre-etched group). However, this was not confirmed by the results of this study. An explanation may be offered by SEM examination of teeth prepared with both protocols (Figures 13 and 14). The surface prepared according to the P+/E+ protocol showed slightly less surface roughness, which may explain the inferior bond strength. Alternatively, pumicing, pre-etching, and etching from the SEP may 'over prepare' the enamel surface, similar in concept to some studies that showed beyond an optimal conventional etching time, bond strengths remain the same or may actually decrease.[27-29] Alternatively, despite rinsing, pumice may have remained on the tooth and affected bond strength. Nevertheless, exposing enamel to both pumicing and a short acid-etch pretreatment when bonding with SEPs is not a routine clinical protocol and would unlikely be adopted since only pumicing (P+/E-) or pre-etching (P-/E+) protocols provide clinically acceptable bond strength[30], are simpler, and less time-consuming.

An added variable in this study was establishing a salivary pellicle on the enamel surface. Few, if any, SEP bonding studies have considered the effects of a salivary pellicle. Turk et al [31] examined whether saliva contamination affects the bond strength of SEPs, by brushing saliva across the prepared bonding surface, but the short saliva exposure times may not have been sufficient to form a pellicle. It has been shown by Hannig et al[32] that an initial 10-20 nm layer of pellicle forms after three minutes of immersion in saliva. After two hours it varies between 80-200 nm[33]. In the current study, when no attempt was made to remove the salivary pellicle through pre-etching or pumicing, bonding effectiveness appeared compromised as evidenced by the low bond strength for P-/E-. A randomized clinical trial by Burgess et al[11] and a prospective clinical trial by Lill and Lindauer[15] have confirmed the importance of pumicing in the removal of the salivary pellicle before bonding with SEPs in vivo.

A majority of ARI scores for all four groups were 0 or 1, indicating adhesive was more likely to remain on the bracket as opposed to the tooth after debonding. Clinically this is desirable, as it would require less time for cleanup of the enamel. Another study using pre-coated brackets showed they are less likely to leave adhesive on the tooth compared to when the adhesive is applied to the bracket base at the time of bonding[34]. Not surprisingly, lower ARI scores were observed for teeth that received no pre-treatment. This finding is further corroborated in SEM images that showed a less retentive enamel surface. Enamel fractures were observed among teeth that were pre-etched before SEP bonding. This observation may be cause for concern even if in vitro bond strengths are not directly reflective of in vivo bond strengths. Grubisa et al[35] also reported enamel fractures in a self-etching primer study, but they attributed this to the teeth being stored in formalin. Retief [36] has reported enamel fracture at bond strengths of only 9.7 MPa, reflecting the wide range and variation seen in bonding studies. Cracks in the tooth surface that were not discovered at the time of surface inspection could be another explanation. However, selection of teeth was performed with great care and teeth were re-inspected for defects several times during the study.

For teeth weakened by large restorations or aged teeth with existing cracks, pre-etching when bonding with SEPs may not be recommended. On the other hand, possible indications for pre-etching when using SEPs include rebonding brackets that have debonded during active treatment, bonding in areas of frequent bond failure (second premolars) or areas of increased occlusal interferences (second molars). Further indications may include bonding to enamel which is irregular or aprismatic. This possible indication would encompass bonded lingual retainers, lingual braces and bondable tongue spurs. Another technique which would benefit from increased bond strengths is attaching a chain to surgically exposed impacted teeth which are then covered back over with a gingival flap. Higher bond strengths would reduce the number of repeat surgeries due to bond failures.

The results showed more than adequate bond strengths using a five second pre-etch. However, this may not be practical if bonding more than a few teeth with this technique, as by the time etchant is removed from the first tooth more than five seconds may have elapsed. Clinically, leaving the etchant on for ten seconds may be more realistic, but this could potentially lead to excessive bond strengths when using self-etching primers. The cost benefit ratio also should be considered. A clinical trial would be necessary to determine if the greater expense of self-etching primer, compared with conventional primer, is of such advantage to use a pre-etch/SEP technique over a conventional bonding technique.

SEM analysis provided insight into the bond strength results by examining the surface of enamel after different combinations of surface treatment. Comparison of Figures 7 and 8 show the cleaning efficacy of pumicing in removing the salivary pellicle. However, pumicing did produce surface scratches, but the apparent surface roughness was not appreciably altered. This is consistent with a previous study by Castanho et al.[37] As would be expected, pre-etching with 37% phosphoric acid for five seconds produced an etching pattern (Figure 9) but it is not as distinct as when longer etching times are used.[16] The self-etching primer produced a roughened enamel surface when viewed in cross-section (Figure 10). The SEP contains a methacrylated phosphoric acid ester, which etches and primes simultaneously, therefore the depth of etching is the same as the depth of primer penetration.[38,39] Comparatively (Figures 10 and 11), it was less effective in this regard than the treatment with 37% phosphoric acid (pre-etch), which is in agreement with other studies comparing SEPs to phosphoric acid treatments.[38,40,41] Furthermore, the presence of the salivary pellicle appeared to limit the cross-sectional roughness of enamel when the SEP was used (Figures 11 and 12). In this study, the pellicle may have acted as a barrier to etching the tooth and limited its penetration.

In vitro studies have indicated acceptable bond strengths when using SEPs with pumicing[2]. Additionally, clinical studies have shown relatively few debonds[11,15]. Nevertheless, anecdotal accounts mention that some clinicians are substituting a pumicing step with a pre-etching step during their SEP bonding protocol. Little evidence exists in the literature examining the effectiveness of this practice. The results obtained in this study suggest that pre-etching enamel prior to SEP application allows absolute exposure of the enamel to the SEP, fully removing the saliva pellicle and other barriers to bonding, maximizing primer penetration of the enamel and therefore maximizing bond strength. Clinical studies examining debond and enamel fracture rates are needed before fully endorsing this procedure.

CHAPTER VI

CONCLUSIONS

CONCLUSIONS

- A five second pre-etch with 37% phosphoric acid, when bonding with self-etching primers, gives significantly greater bond strengths compared with pumicing.
- Lowest ARI scores were recorded when the salivary pellicle was left on the tooth while bonding with SEP.
- SEM analysis revealed varying degrees of enamel surface penetration depending on the pretreatment protocol. More surface roughness was produced when the enamel surface was pre-etched for five seconds with 37% phosphoric acid than when pumiced for ten seconds, prior to bonding with SEP.

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