CHAPTER II

LITERATURE REVIEW

The literature review is divided into four parts as follows:

I. Conventional phosphoric acid etching adhesive systems

II. Self-etching adhesive systems

III. Shear bond strength

IV. Failure mode

I. Conventional phosphoric acid etching adhesive systems

In 1955, Buonocore first introduced the so-called acid-etch technique, which enabled the bonding of composite resin to the enamel surface. He demonstrated the increased retention of resin when the enamel was etched with phosphoric acid. Since then, the acid-etch technique has become a standard procedure for surface preparation of enamel prior to resin-based composite restoration. He found that resin could be bonded to human enamel that was conditioned with 85% phosphoric acid for 30 seconds. Today most commercially available etchants contain 30% to 40% phosphoric acid by volume, which provides enamel surfaces with the most retentive condition (Reynold, 1975; Ben-Amar *et al*., 1987).

Clinically, the etching of enamel creates micro-porosity within the enamel that allows the resin to penetrate and to polymerize within the etched enamel rods. After polymerization of the resin bonding agent, a durable attachment to the enamel is achieved by micro-mechanical retention (Combe, 1986; Hannig *et al*., 1994). The acid-etch technique includes the following steps of enamel conditioning: acid etching, water rinsing, air drying, and application of the bonding agent (Hannig *et al*., 1994). Standard 37% phosphoric acid typically dissolves about 5-10 μm of enamel surface and creates a zone of etched enamel rods for about 15-25 μm (Ibsen and Neville, 1974; Power and Messersmith, 2001) (Figures 2.1 and 2.2). The etching process created calcium mono-phosphate and calcium sulfate by-products that must be removed by a vigorous water rinse. Care must be taken to lightly dab the enamel surface with the acid etchant to avoid polishing or fracturing the exposed enamel rods. After bond failure, teeth can be prepared for re-bonding. Scanning electron microscopic observations have revealed retained fragments of composite adhesive on the enamel (Power and Messersmith, 2001) (Figure 2.3 and 2.4).

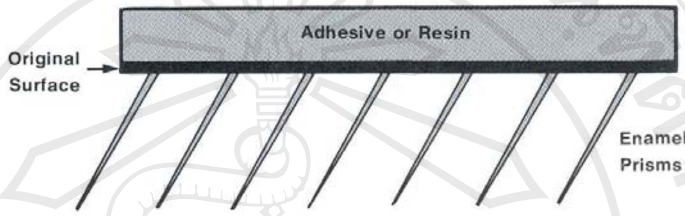


Figure 2.1 Non-conditioned enamel surface (Ibsen and Neville, 1974).

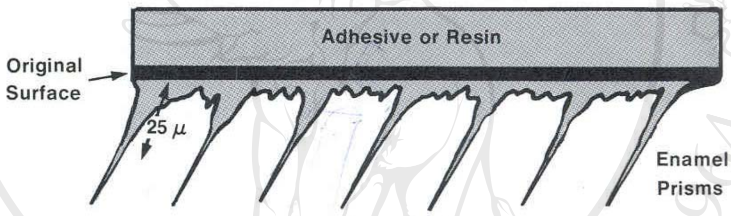


Figure 2.2 Conditioned enamel surface with 37%phosphoric acid (Ibsen and Neville, 1974).

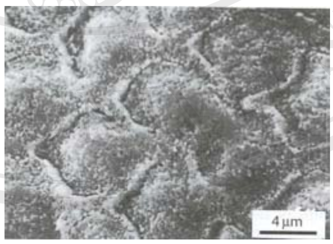


Figure 2.3 Typical etching pattern of human enamel, showing enamel rods with micro-porosities (Power and Messersmith, 2001).

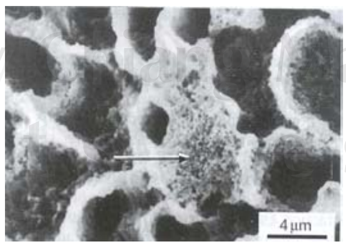
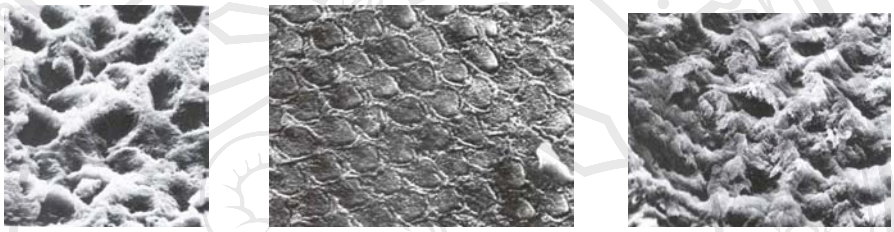


Figure 2.4 Re-etched human enamel prepared for re-bonding after bond failure. Retained fragments of resin composite adhesive are indicated by the arrow (Power and Messersmith, 2001).

Patterns of etched enamel with phosphoric acid

The patterns of etched enamel are varied. The most common (Type 1) involves preferential removal of the enamel prism cores, the prism peripheries remaining intact. Type 2 is the opposite of Type 1, involving preferential removal of the peripheries with the cores being left intact. Type 3 contains areas which resemble both Types 1 and 2 along with some less distinct areas where the pattern of etching appears to be unrelated to the enamel prism morphology (McCabe and Wall, 1998) (Figure 2.5).



A B C

Figure 2.5 Types of pattern of etched enamel A, Type 1. B, Type 2. C, Type 3 (McCabe and Wall, 1998).

Iatrogenic effects of etching with phosphoric acid

While most clinicians accept acid etching of enamel as a routine technique, there are some possible iatrogenic effects as follows:

1. Demineralization of the most superficial layer of enamel and excessive enamel loss during etching

The degree of depth of enamel surface removed during the etching procedure depends on the type of acid used, the acid concentration, the duration of etching and the chemical composition of the enamel (Barkmeier, 1986; Retief, 1986; Miyazaki *et al*., 2000). Acid etching of enamel removes about 10-20 μm of enamel, resulting in loss of acquired fluoride in the outer 10 μm of the enamel surface (Power and Messersmith, 2001). Phosphoric acid has been blamed for decalcification and for the development of white spot lesions around bonded orthodontic appliances (Gorelick *et al*., 1982; Ogaard *et al*., 1988; Boyd, 1993). Appropriate concentration of phosphoric acid can remove 5 μm of enamel surface and also selectively decalcify the enamel to a depth of

15-120 μm. Stronger acids do not decalcify selectively. Weaker acids react too slowly with enamel (Reynolds, 1975).

2. Risk of contamination

Conventional composite resins require the use of 3 different agents (enamel conditioner, primer, and adhesive resin) to bond orthodontic brackets to the enamel. Because of their hydrophobic properties, these products require completely dry and isolated fields to obtain clinically acceptable bond strengths. When etched enamel becomes wet, most of the pores become plugged, and resin penetration is impaired, resulting in resin tags of insufficient number and length to penetrate all of the etched pores adequately. Even momentary saliva contamination adversely affects the bond because saliva is deposited on the organic adhesive coating in the first few seconds of exposure and is resistant to removal by washing, thus preventing the bonding agent from infiltrating into the enamel prisms. Thus, it would be disadvantageous to be able to bond to enamel in a wet environment, particularly in hard-to-reach areas, such as around second molars or partially erupted and impacted teeth. Moisture contamination is considered the most common reason for bond failure (Zachrisson, 1977; Gwinnette, 1998; Cacciafesta *et al*., 2003).

3. Mechanical damage to the enamel during de-bonding and removal of the remaining resin after acid etching

An additional 6-50 μm of enamel is estimated to be lost on de-bonding. Even with the most careful de-bonding technique, possible iatrogenic effects of etching of enamel are fracture and cracking of enamel upon de-bonding (Brown *et al*., 1978; Diedrich, 1981; Joseph and Rossouw, 1990; Power and Messersmith, 2001). Cohesive fracture of enamel may occur as a result of excessive etching and/or imperfections in the subsurface enamel (Sheykholeslam and Brandt, 1977).

4. Increased surface porosity with possible staining

Etched enamel is porous, making it susceptible to staining, although the porosities are filled by precipitates from saliva over time (Power and Messersmith, 2001).

5. Resin tag retained in enamel with possible discoloration of resin

Resin tags that remain in the enamel after de-bonding change color with time (Power and Messersmith, 2001).

6. Rougher surface, if over-etched (Power and Messersmith, 2001).

II. Self-etching adhesive systems

The self-etching adhesive system was first introduced in the early 1990s and this system was advocated to be applied only on dentin. Current self-etching adhesives provide monomer formulations for simultaneous conditioning and priming of both dentin and enamel. Self-etching primer agents combine conditioning and priming agents into a single self-etching primer solution, eliminating the need for separate procedural steps for etching, rinsing, and drying (Meerbeek *et al*., 2001).

Self-etching primers are mainly aqueous solutions of acid monomers, such as phosphate ester, carboxylic acid, or hydroxyethyl methacrylate (Haller, 2000).

Pattern of etched enamel with self-etching primer

Yoshiyama *et al*., (1996), in describing the pattern of etched enamel with self-etching primer reported that the primer is not rinsed with water after application, but air dried only. When the primer dissolves the hydroxyapatite, calcium and phosphate ions are not dissolved from the hydroxyapatite crystals but are suspended in the aqueous solution of the primer. When the water in this aqueous solution is evaporated during air drying, the concentrations of suspended calcium and phosphate within the primer could exceed the solubility product constants for a number of calcium phosphate salts. These high concentrations of calcium and phosphate tend to limit further dissolution of the apatite due to the common ion effects of calcium and phosphate and thereby limit the depth of enamel surface demineralization. On the other hand, it is very likely that the binding of calcium ions to the phosphate residues in primer molecules contribute to the inactivation of the molecule’s acidity. In addition, evaporation of water during air drying, as well as light curing of the primer and of the subsequently applied bonding agents, might restrict and inhibit the self-etching effect of the primer molecules.

Miyazaki *et al*. (2002) reported that distinct differences in the pattern of etched enamel result from the application of self-etching primers to the enamel surface, depending on the particular product used. These differences are understandable in view of the specific esters contained in the self-etching primers. Self-etching primer is removed from the enamel surface by an intensive rinsing with alcohol and acetone for the manufacturer-recommended treatment times. Due to its intrinsic acidity, the self-etching primer dissolves the enamel surface and thereby creates a three-dimensional micro-retentive surface pattern, while simultaneously promoting monomer infiltration. Depth of enamel demineralization and penetration depth of the bonding agent are identical, since both processes run parallel to each other. The morphological study of the etched-enamel surface demonstrated that the application of the self-etching primer did not create a deep enamel etching pattern as did the application of phosphoric acid (Miyazaki *et al*., 2002).

Bishara *et al*., (1998) compared adhesive penetration into enamel surfaces etched with phosphoric acid and with self-etching primer. They showed, in scanning electron microscope (SEM) photographs, that resin tags are thick and uniform, penetrating into the etched enamel in the case of etching with phosphoric acid. In the case of etching with self-etching primer, resin tags are thinner and less uniform than with phosphoric acid (Figures 2.6 and 2.7).

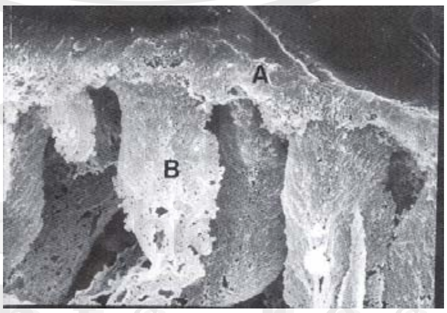


Figure 2.6 SEM photograph of adhesive penetration into enamel surfaces etched with phosphoric acid. A-Adhesive resin, B-Adhesive resin tag (Bishara *et al*., 1998).

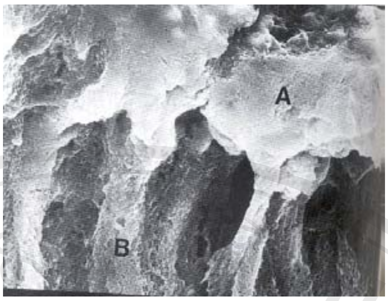
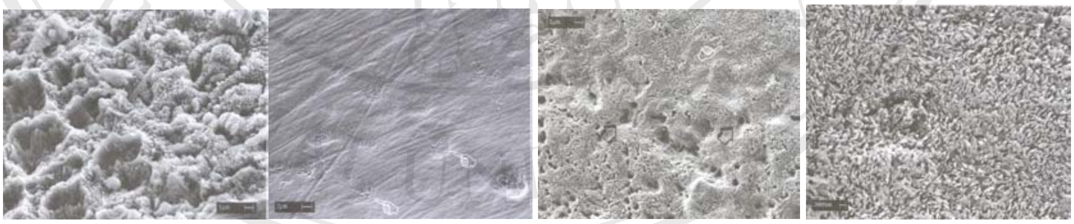


Figure 2.7 SEM photograph of adhesive penetration into enamel surfaces etched with the self-etching primer. A-Adhesive resin, B-Adhesive resin tag (Bishara *et al*.,1998).

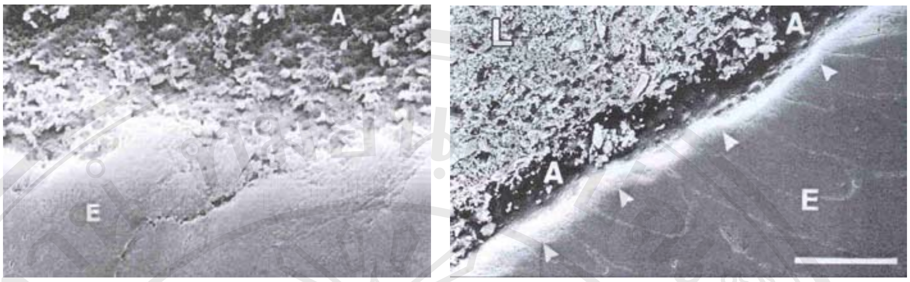
Pashley and Tay, (2001) compared enamel surfaces following etching with phosphoric acid and three self-etching primers: Clearfil Mega Bond, Non-Rinse and Prop L-Pop. In SEM micrographs of enamel surfaces after application of 32% phosphoric acid they showed that differential dissolution of prism cores and the boundaries of the etched area were more clearly evident than was the case in enamel surfaces after application of any of the three self-etching primers: Clearfil Mega Bond, Non-Rinse and Prop L-Pop respectively (Figure 2.8).



A B C D

Figure 2.8 SEM micrograph showing enamel surfaces after application of 32% phosphoric acid (A) and three self-etching primer agents: Clearfil Mega Bond (B), Non-Rinse (C), and Prop L-Pop (D) (Pashley and Tay, 2001).

Meerbeek *et al*., (2001) compared enamel surfaces following the use of strong and mild self-etching adhesives. In Fe-SEM micrographs, that the interaction of self-etching adhesives depends on the pH and the etching aggressiveness of the adhesives. Strong self-etching adhesives resulted in the formation of “micro-tags” and a clearly detectable effect at the enamel surface. Mild self-etching adhesives hardly showed any detectable effect at the enamel surface (Meerbeek *et al*., 2001) (Figure 2.9).



A B

Figure 2.9 Fe-SEM micrograph showing enamel surface after application of strong self-etching adhesive (A) and mild self-etching adhesive (B) (A-Adhesive, E-Enamel) (Meerbeek *et al*., 2001).

Advantages of self-etching adhesive systems

The advantages of self-etching adhesive systems are as follows:

1 Fewer clinical steps

A unique characteristic of self-etching adhesive systems is that they combine conditioning and priming agents into a single self-etching primer solution.

2. Shorter procedure time

Self-etching adhesives were developed to combine conditioning and priming agents into a single self-etching primer for simultaneous use on enamel and dentin, thus eliminating the need for separate etching, rinsing, and drying procedures (Manhart *et al*., 1999; Bishara *et al*., 2001).

3. Less demineralization

Using self-etching adhesive systems produces less demineralization than conventional phosphoric acid adhesive systems because the depth of the demineralization is identical to that of the primer penetration (Miller, 2001; Buyukyilmaz *et al*., 2002).

4. Bonding in areas difficult to isolate (Retief, 1978).

Use of the self-etching primer reduces potential for error and contamination during the bonding procedure (Bishara *et al*., 2002). In most contaminated conditions (water/saliva contamination), the self-etching primer has higher strength values than either hydrophilic or conventional primers. The self-etching material is the least influenced by water and saliva contamination in terms of bond strength values and the type of failure site, except when water and saliva moistening occurred after the recommended 3-second air burst (Cacciafesta *et al*., 2003). These findings agree with those of Granhi *et al*. (2001). However, Whebater *et al*. (2001) found no difference in shear bond strength between conventional, hydrophilic and self-etching primers when the enamel is contaminated with saliva after priming.

5. Simultaneous use on both enamel and dentin (Nishida *et al*., 1993).

When self-etching primer is applied to dentin, the smear layer is modified by the infiltrating resin to from a hybridized smear layer, the dentinal tubules are sealed simultaneously with a resin-infiltrated smear plug, resulting in minimal or no sensitivity (Wei and Tay, 2003) (Figure 2.10).

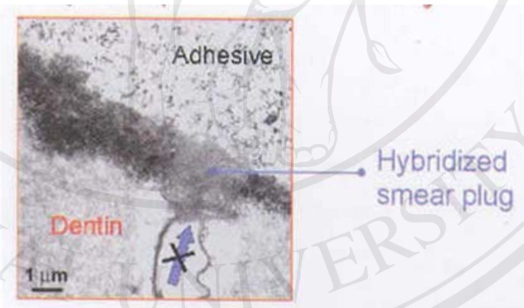


Figure 2.10 Hybridized smear plug created from using a self-etching adhesive system (Wei and Tay, 2003).

6. Cost–effectiveness for clinician as well as patients (Bishara *et al*., 2002).

Disadvantages of self-etching adhesive systems

1. The effectiveness of self-etching adhesive systems on properly etching the enamel is less predictable than the result obtained with phosphoric acid (Hera *et al*., 1999; Kanemura *et al*., 1999; Bishara *et al*., 1999; 2001).

2. The self-etching solution must be refreshed continuously because its liquid formulation can not be controlled where it is placed (Ferrari *et al*., 1997).

III. Shear bond strength

Definition

The maximum force per unit area that opposes the sliding of one plane of a material on an adjacent plane in a direction parallel to the applied force without causing a fracture. (เจน รัตนไพศาล, 2533; Daskalogiannakis, 2000)

Shear force

The internal induced force that opposes the sliding of one plane on an adjacent plane in a parallel direction (เจน รัตนไพศาล, พ.ศ. 2533) (Figure 2.11).

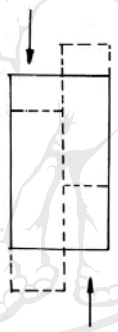


Figure 2.11 Direction of shear force that opposes the sliding of one plane on an adjacent plane (เจน รัตนไพศาล, พ.ศ. 2533).

Shear bond strength test

The subcommittee on testing methods of the International Association of Dental Research, in 1967, recommended a tensile test for measuring bond strength of resin to dental hard tissue. However, for the bracket-adhesive-enamel bond, shear force is likely to be most critical *in vivo* (Alexander *et al*., 1993).

Arici and Regan (1997) said that shear tests tend to simulate the direction of the force applied to de-bond the brackets at the end of treatment or resistance to occlusal forces, whereas a tensile test indicate possible failure due to archwire ligation.

Fox *et al*. (1994) wrote a critique of bond strength testing in orthodontics, based on an extensive review of the literature and proposed a standard protocol for further bond strength testing in orthodontics. The following criteria were taken into account when the protocol for the present *in vitro* study was developed.

1. Surface premolar enamel should be used on teeth extracted from adolescent patients for orthodontic reasons.

2. Teeth should be used within 6 months after extraction.

3. After bonding, the specimens should be immersed in water for 24 hours at 37°C.

4. De-bonding should take place on an Instron® universal testing machine or equivalent machine at a cross-head speed of 0.1 millimeter per minute.

5. Care should be taken to ensure that the point of application and the direction of the de-bonding force is the same for all specimens.

6. All least 20, and preferably 30, specimens should be used per test.

7. Sites of failure should be reported.

8. Statistical analysis should include survival analysis, to give a prediction of the clinical situation.

9. Bond strengths should be quoted in either Newtons or MegaPascals.

Clinically useful bond strength for orthodontic need

In restorative dentistry the highest bond strength to tooth structure is desirable. In contrast, orthodontic bond strength must be sufficient to retain the brackets but allow easy clean-up of adhesive when the case is completed and the brackets are removed.

Reynolds (1975) and Power and Messersmith (2001) suggested that a minimal bond strength of 6 to 8 MPa was adequate for most clinical orthodontic needs, because these values were considered to be able to withstand masticatory and orthodontic forces. To improve retention through a larger bonding area, a larger bracket should be selected.

Many i*n vitro* studies have reported that the use of self-etching adhesive systems to bond orthodontic brackets to the enamel surface was inferior when compared with conventional phosphoric acid etching adhesive systems because of shallow etching patterns (Hera *et al*. ,1999; Kanemura *et al*.,1999; Bishara *et al*. ,1999; 2001). On the other hand, many reports found that the use of self-etching adhesive systems gave bond strength values similar to those of conventional phosphoric acid etching adhesive systems (Rueggeberg *et al*., 2000; Bishara *et al*., 2002), provided clinically acceptable shear bond strength (Bishara *et al*.,1998; 2002) and was an effective alternative to conventional phosphoric acid etchants in conditioning the enamel surface (Hannig *et al*., 1994; Rueggeberg *et al*., 2000 Toledano *et al*., 2001; Bishara *et al*., 2002; Wei and Tay 2003).

In clinical studies, Miller (2001) found that self-etching primer (Prompt L-Pop) did not appear to produce a statistically significant reduction in bond failure rates when compared with hydrophilic primer (Tranbond MIP) over a 6-month period. Asgari *et al*. (2002) found that bond failure rate using Transbond Plus Self Etching Primer was significantly less than the bond failure rate in those quadrants where a 37% phosphoric acid etchant was used.

Effects of important variables on shear bond strength

There are many important variables which effect to the shear bond strength as follows:

1. Structure of enamel

In each tooth, enamel surface played a major role in bond strength. Deciduous teeth more frequently had areas of prismless enamel than did permanent teeth. Prismless zones may negatively influence the retention of resin. In order to remove such layers, prolonged etching time or mechanical removal of surface enamel prior to etching has been recommended (Sheykholeslam and Bounocore, 1972).

Nordenvall *et al*. (1980) compared surface irregularity, using a scanning electron microscope, after 15 and 60 seconds of etching with 37% percent phosphoric acid solution on enamel surfaces from deciduous, young and old permanent teeth.

They found that in deciduous teeth, there was no difference in surface irregularity between the etching periods. For young permanent teeth, 15 seconds of etching created more retention than 60 seconds, but for old permanent teeth the reverse was found. There were great variations in the effect of acids on the enamel surface, because the enamel surfaces of old permanent teeth had different composition from that of newly erupted teeth due to wear and replacement of organic material by minerals during the maturation process.

Sheen *et al*. (1993) reported that the bond strength of old permanent teeth was greater than the bond strength of younger teeth, regardless of etching time. The older teeth became harder, more resistance to decay and less permeable to fluid than the younger teeth. Thus, the enamel became harder with age and reinforced the tensile bond strength

2. Differences among teeth

There are significant differences in shear bond strengths between different tooth types (Hobson *et al*., 1999; Linklater and Gordon, 2001). Those differences may relate to gross anatomical variability. The prismless enamel tends to be more common on posterior teeth (Whittaker, 1982). The different tooth types exhibit biological variation in their etch pattern after acid priming and influence the bond strength values. The extent of etch achieved decreases toward the distal end of each arch and is significantly less on the first molars than on the incisors (Mattick and Hobson, 2000). However, differences in bond strength between buccal and lingual/palatal surfaces of human premolar teeth have not been found (Heringer *et al*., 1993; Wang *et al*., 1993).

3. Effects of fluoride

The presence of fluoride ions is the main factor associated with mottled enamel. The ingestion of fluoride damages both the ameloblasts and the matrix. Teeth with a higher concentration of fluoride are generally considered more resistant to acid etching than normal teeth and require an extended etching time. In one study, bond strengths in a group of severely and moderately fluorotic teeth, even with additional time for acid etching were about 40% lower than bond strengths to normal teeth, although a group of mildly to moderately fluorotic teeth from young adults showed similar bond strengths when compared to normal teeth (Opinya and Pameijer, 1986).

4. Type and concentration of acid

In another study, etching with 10% or 37% phosphoric acid produced the highest bond strengths (28 MPa) to enamel. The use of 10% maleic acid for etching resulted in a lower bond strength (18 MPa) (Wang *et al*., 1994). No differences in bond strengths were observed when enamel was etched with phosphoric acid ranging in concentration from 2% to 37% (Carsenten, 1995).

5. Duration of etching

No differences in bond strength are detected between 15 seconds and 60 seconds etching with 37% phosphoric acid. However, shorter etching times caused less enamel damage on debonding. Scanning electron microscopy showed that etching with 37% phosphoric acid for at least 30 seconds produced more optimal etching patterns than etching for 15 seconds (Olsen *et al*., 1996).

6. Use of pumice with or without fluoride

Pumice or prophylactic paste is often used to clean the enamel surface before acid etching and bonding. However, bond strength appears to be unaffected whether pumice is used or not (Lindauer *et al*., 1997). Use of a fluoridated pumice or paste with varying fluoride concentrations also did not affect bond strength or location of bond failure (Damom *et al*., 1996).

7. Contamination

There is a reduction of approximately 50% in the mean shear bond strength when resin composite adhesive is bonded to saliva-contaminated etched enamel surfaces compared with the uncontaminated etched enamel surface (Thomson *et al*., 1981; Pashley *et al*., 1988; Xie *et al*., 1993; El-Kalla and Garcia-Godey, 1997; Benderli *et al*., 1999; Kaneshima *et al*., 2000).

Blood contamination lowered enamel and dentin tensile bond strengths by 33% to 70% respectively (Xie *et al*., 1993). Blood contamination before acid etching or self-etching primer application did not affect the bond strength when blood was rinsed away with water (Kaneshima *et al*., 2000). But, blood contamination of the self-etching primer during bonding significantly decreased the shear bond strength of the bonded orthodontic brackets to the enamel surface (Oonsombat *et al*., 2003).

8. Bracket

A fine mesh base gave higher mean bond strength compared with a coarse mesh and both mesh bases showed greater bond strength compared with an undercut base (Smith and Reynolds, 1991).

IV. Failure mode

A failure mode is form of bond failure that consists of adhesive and cohesive failures. Adhesive failure includes failure at the adhesive/enamel interface or the adhesive/bracket interface. With bond failure at the adhesive/enamel interface, most of the resin remains on the bracket and practically none on the enamel surface. With bond failure at the interface of the bracket and adhesive, practically all the resin remains on the tooth surface. Cohesive failure occurrs within enamel, within the adhesive or even within the bracket. Cohesive failure within enamel occurrs as a result of excessive etching and/or imperfections of the subsurface enamel. Cohesive failure within the bracket occurs with plastic or ceramic brackets (Sheykholeslam and Brandt, 1977; Power and Messersmith, 2001) (Figure 2.12 and 2.13).

A B

Figure 2.12 Adhesive failures. (A) Interface of the adhesive and enamel, (B) Interface of the adhesive and bracket (Sheykholeslam and Brandt, 1977).

A B C

Figure 2.13 Cohesive failures. (A) Within the enamel, (B) Within the adhesive, (C) Within the bracket (Sheykholeslam and Brandt, 1977).

The failure sites were determined by examining both the debonded enamel surface and the bracket under a stereozoom microscope. The failure sites were divided into five locations: within the enamel, adhesive/enamel interface (0-25% of the residual adhesives left on the tooth), within the adhesive (25-75% of the residual adhesives left on the tooth), adhesive/bracket interface (75-100% of the residual adhesives left on the tooth) and within the bracket (Alexander, 1993; Jou, *et al*., 1995)

Pus and Way (1980), Maijer and Smith (1981), Thompson and Way (1981), Kinami *et al.* (1988), Kinch *et al*. (1989) and Sinha *et al*. (1995) concluded that failure at the adhesive/enamel interface was advantageous. The advantages were that: residual adhesives on debonded tooth could be removed much more easirly, save clinical time and decrease pain during removal of residual adhesives from debonded tooth. Failure at the adhesive/bracket interface resulted in adhesive remnants being firmly attached to the enamel. Removal of large amounts of residual adhesives can be time consuming and may cause enamel surface damage (Zachisson and Artun, 1979).

On the other hand, Bennett *et al*. (1984), Artun and Bergland (1984), Meister (1985) and McGuinness (1992) concluded that failure at the adhesive/ bracket interface or within the adhesive was more desirable than at the adhesive/enamel interface. They suggested that removal of the residual adhesives on debonded enamel surfaces should be accomplished with the proper instruments. Enamel fracture and high enamel porosity has been reported at the time of bracket debonding when bond failure occurred at the adhesive/enamel interface. It is possible that the depth of etched enamel surface may be a contributing factor to the incidence of enamel fracture.

Possible causes of bond failure at the adhesive/enamel interface

(Power and Messersmith, 2001)

Possible causes of bond failure at the adhesive/enamel interface (adhesive left on bracket, little left on tooth) are as follows:

1. Contamination of the etched enamel by saliva, moisture or oil from the water line.

2. Insufficient rinsing of etchant from the tooth before bonding.

3. Inadequate drying of enamel surface, precluding penetration of resin.

4. Over-etching demineralized enamel, reducing depth of resin tag penetration, and removing excessive amounts of enamel.

5. Faulty bonding materials are unlikely, but expiration dates should be checked and care taken in handling of materials.

6. No activator placed on enamel surface when a no-mix adhesive is used.

7. Tooth surface required special preparation because of amalgam, gold, ceramic, or other restorative material.

Possible causes of bond failure at the adhesive/bracket interface

(Power and Messersmith, 2001)

Possible causes of bond failure at the adhesive/bracket interface (adhesive left on tooth, little left on bracket) are as follows:

1. Excessive force exerted on bracket from occlusion, or excessive force from appliance.

2. Movement of bracket during initial setting of adhesive.

3. Contaminated bracket mesh (oil from hands, glove powder, or rebounded bracket).

4. Adhesive not “buttered “into base firmly.

5. Activator not placed on bracket in paste-primer system.

6. Inadequate cure of light-cured composite resin (output of light curing unit should be checked).

7. Special primer required (plastic brackets).

Bishara *et al*. (1998) and Buyukyilmaz *et al*. (2002) indicated that the conventional phosphoric acid etching system had greater residual adhesive on the teeth than the self-etching adhesive system. These findings disagreed with the results of Bishara *et al*. (2001) that indicated that there was significantly more residual adhesive on the teeth that were treated with self-etching than on those teeth that were bonded with the conventional adhesive system.

Cacciafesta *et al*. (2003) reported that the conventional phosphoric acid etching adhesive system used in a dry field showed a significantly greater frequency of failure at the adhesive/bracket interface, but when it was used with either water or saliva contamination, it debonded more frequently at the adhesive/enamel interface. This agreed with the results of Webster *et al*. (2001). This finding was probably due to the hydrophobic properties of primer and the composite resin. Moreover, no significant differences in debond locations were found among the groups bonded with the self-etching primer under the various enamel conditions (dry, water application before or/ and after priming, saliva contamination before or/and after priming).