CHAPTER V

DISCUSSION, CONCLUSION and SUGGESTION

Discussion

In the present study, two self-etch adhesives and one total-etch adhesive were evaluated for their bond strengths after contaminating the dentin surface with a commonly used topical anesthetic gel. A micro-tensile bond strength testing method was chosen to evaluate the bond strength between dentin and resin composite by using three adhesive systems. The micro-tensile bond test is considered as acceptable testing method and is now very popular among researchers (Schreiner *et al.*, 1998; Goracci *et al.*, 2004). With the micro-tensile bond strength testing method, the prevalence of cohesive failure in dentin is minimized (Sano *et al.*, 1994) and the bond strength depends upon the quality of the bonded surface (Schreiner *et al.*, 1998). Advantages of the micro-tensile testing method stated by Pashley *et al.* (1995) are: 1) more adhesive failure, fewer cohesive failure; 2) higher interfacial bond strengths obtained; 3) possible measurement of regional bond strengths; 4) possible calculation of means and variances for single teeth; 5) testing of adhesion at irregular surfaces; 6) testing of very small areas; and 7) facilitating the failure analysis. Moreover, multiple specimens can be obtained from a single tooth (Armstrong *et al.*, 1998; Goracci *et al.*, 2004). However, disadvantages of the micro-tensile testing method are those of technically demanding and labor intensive. Furthermore, an aggressive specimen preparation may induce defects at the interfacial bonded areas resulting in low bond strengths even pre-testing debonded specimens (Van Meerbeek *et al.*, 2003; De Munck *et al.*, 2005). The bonded specimens can be easily broken, therefore, special care must be taken during the specimen preparation. In the present study, the specimen preparation was carefully performed to avoid defects on the bonded areas and there was no single debonded specimen during the specimen preparation.

All bond strengths obtained in the present study were more than 20 MPa in all adhesives used. Hence, they were strong enough to resist contraction forces of resin composites (Pashley *et al.*, 1995). Sano *et al.* (1994) demonstrated high levels of micro-tensile testing bond strength values comparable to the high levels obtained from the present study. They explained that larger specimens may contain more defects when compared to smaller specimens and the defects and/or stress distribution in smaller surface areas are more homogeneous than that in the larger areas. With the micro-tensile bond strength testing, the prevalence of cohesive failure is minimized. Failure analysis by SEM in this study found that there was no cohesive failure in dentin and resin composite, that is in agreement with Sano *et al.*' s work (1994).

Results from the present study showed that the bond strengths of one-bottle total-etch adhesive (Single Bond Plus) were significantly higher than those of self-etch adhesives (Clearfil Protect Bond and Clearfil Tri-S Bond). These results are similar to many studies where the total-etch adhesive systems produced higher bond strengths when compared to other systems (Tjan *et al.*, 1996; Frankenberger *et al.*, 2001; Van Meerbeek *et al.*, 2001; Goracci *et al.*, 2004; Say *et al.*, 2005). In contrast, many studies found no significant difference when self-etch adhesives were compared with total-etch adhesives (Cardoso *et al.*, 1998, 2004; Kanemura *et al.*, 1999; Van Meerbeek *et al.*, 2003; Kiremitci *et al.*, 2004; De Munck *et al.*, 2005).

Single Bond Plus is a one-bottle total-etch adhesive system that combines priming and bonding procedures together with a separate etching procedure. Single Bond Plus uses 35% phosphoric acid to remove smear layer and clean the bonding surface. This adhesive contains ethanol as the water chaser, so it is less sensitive to different degrees of moisture than acetone (Cardoso *et al.*, 2004). High bond strengths produced by Single Bond Plus may be due to the smear layer removal via acid etching as well as the penetration ability of resin monomer by agitation of adhesive monomer, which is necessary to enhance and optimize the bond strength.

Clearfil Protect Bond and Clearfil Tri-S Bond are mild self-etch adhesives. Both adhesives contain MDP as acidic polymerizable monomer. MDP is considered a favorable adhesive monomer (Fusayama, 1993; Moll *et al.*, 2002; Lopes *et al.*, 2004) since it has 10 methyl groups to increase affinity to dental tissue and it retains its hydrolytic stability in conjunction with acidic pH values (Cardoso *et al.*, 2004). MDP can have an additional chemical bonding potential to the calcium in the remaining hydroxyapatite (Van Meerbeek *et al.*, 2001, 2003; Yoshida *et al.*, 2004; Atash and Van Den Abbeele, 2005). However, bond strengths of both adhesives were lower than Single Bond Plus. Thus, chemical bond might have less influence on the bond strength.

In the present study, the bond strengths of Clearfil Tri-S Bond (1-step self-etch adhesive) were not different from those of Clearfil Protect Bond (2-step self-etch adhesive). This finding is similar to a recent study by Kiremitci *et al.* (2004). However, some studies have shown that the bond strengths of 1-step self-etch adhesives were lower than those of other adhesive systems (Moll *et al.*, 2002; Van Meerbeek *et al.*, 2003; Cardoso *et al.*, 2004; Goracci *et al.*, 2004; De Munck *et al.*, 2005).

The bond strength values of 1-step self-etch adhesive in this study, which are not different from 2-step self-etch adhesive, may be due to both adhesives are mild adhesives. The bonding mechanism may not different from each other. But Clearfil Tri-S Bond is 1-step self-etch adhesive that combines 3 functions of etching, priming and bonding in a single step. Both hydrophilic and hydrophobic monomers are blended in a high concentration of solvents to keep them in solution (Van Landuyt *et al.*, 2005). The presence of HEMA in the mixture may lower the vapor pressure of water from the adherent surface. If water was not completely eliminated, residual water may entrap in adhesive layers, resulting in low bond strengths. The SEM images of Clearfil Tri-S bond showed voids which might due to water entrapment on the fracture surfaces, although the dentin surfaces are blown with high pressure air as per the manufacturer's instruction.

After acid etching of dentin, it has been recommended that the conditioned dentin surface be maintained in a visibly moist condition, known as moist bonding technique (Kanca, 1992; Tay *et al.*, 1996). The presence of water on the dentin surface is essential in maintaining and preventing the structural integrity of the demineralized surface collagen from collapsing and facilitating resin infiltration. The wet and moist bonding technique are recommended to improve bond strengths of adhesive systems that are dissolved in high volatile solvent such as acetone and ethanol (Kanca, 1992; Tay *et al.*, 1996; Al-Ehaideb and Mohammed, 2000; Frankenberger *et al.*, 2001). Kanca (1991) found that if the collagen fiber was left visibly moist after acid etching, the bond strength could be dramatically increased, especially with acetone-base bonding systems. He explained that this was because of the properties of acetone-water interactions. The acetone and resin mixture will chase and displace water. If the dentin surface is dried, the primer molecule will not spread through the dentin surface, resulting in inadequate adaptation between resin and dentin surface.

It is known that bond strength of total-etch adhesive systems can be adversely affected by different degrees of moisture (Xie *et al.*, 1993; Tay *et al.*, 1996; Moll *et al.*, 2002). Over-drying of the acid conditioned dentin, even very brief drying can result in incomplete resin infiltration. The incomplete infiltration of resin monomer within the dentin subsurface and hybrid layer could result in a weak zone that is susceptible to long term degradation (Tay *et al.*, 1996; Prati *et al.*, 1998; Perdigao *et al.*, 2000; Tay and Pashley, 2001). On the contrary, if the water in the saturated collagen network is not sufficiently removed, water will compete with the infiltrating resin for space within the collagen mesh (Tay *et al.*, 1996). It is possible that the excess moisture dilutes the primer, thus producing a weak hybrid layer (Xie *et al.*, 1993). When primer/adhesives are applied, the solvent may diffuse into the excess water, forming blister-like spaces and resin globules instead of resin tags within the hybrid layer (Atash and Van Den Abbeele, 2005). Thus, the total-etch adhesive is still considered as a technique-sensitive system (Al-Ehaideb and Mohammed, 2000; Miyazaki *et al.*, 2000). Miyazaki *et al.* (2000) found that with fewer components and applications steps, 2-step total-etch adhesive (Single Bond) produced lower bond strength and larger variations than self-etch adhesive when applied by different operators.

This *in vitro* study was done on flat dentin and in the laboratory condition so it was easy to form a uniform wetness of dentin surfaces and a uniform thickness of the hybrid layer. In the clinical situations, this technique might not be effective because there is a tendency to overly dry some areas of complex cavities and overly wet the area of line-angles.

There is little information in the literature on how topical anesthetic gels affect the bond strength to dentin. However, most studies about the effect of contaminants on bond strength of bonding systems showed similar results. The contamination occurred before collagen fibers were exposed by either acid etching or self-etch primer application, the contamination presented almost no influence on the bond strength (Kaneshima *et al.*; 2000; Park and Lee, 2004). Contamination of the dentin surface where collagen fibers had been exposed via acid etching or an application of primer of self-etch adhesive, the bond strength will be decreased (Xie *et al.*, 1993; Kaneshima *et al.*, 2000; Sung *et al.*, 2002; Park and Lee, 2004).

Kaneshima *et al.* (2000) demonstrated that a SEM image of the sample contaminated by blood after acid etching did not present any differences in surface characteristics compared to that of the non contaminated sample when the blood was washed away with water. SEM photographs also showed that re-etching re-opened some of the dentinal tubules obstructed with contaminants (cements) (Powers *et al.*, 1995).

It is known that phosphoric acid etchants have enough acidity to remove contaminants such as saliva or blood (Xie *et al.*, 1993). Previous studies have shown that additional acid etching for 10 seconds beyond the manufacturer's recommendation is not detrimental to bond strength (Kanca 1992; Xie *et al.*, 1993). It has been reported that the bond strength could be almost completely recovered by re-etching and re-priming of self-etch primer adhesive (Xie *et al.*, 1993; Kaneshima *et al.*, 2000; Park and Lee, 2004).

However, a study by Hiraishi *et al.* (2003) demonstrated that re-etching of contaminated dentin surface for 15 seconds did not restore the bond strength to values close to the control. It seemed that re-etching with phosphoric acid caused a significant decrease in bond strengths. A demineralized dentin layer was probably too thick and at the same time collagen fibril network collapsed, resulting in inadequate penetration into the collagen fibers of adhesive monomer.

In order to regain optimal bond strengths, it was not sufficient to dry or wash of the contaminated (saliva) surface after application of the primer. The bond strength could be recovered after reapplication of the primer (Park and Lee, 2004). It is likely that the bond strength was recovered, owing to the hybrid layer reformation after removing the unstable primer layer.

In the present study a topical anesthetic gel was applied on dentin surface, left for 5 minutes, and then rinsed with water for 30 seconds. If there is topical anesthetic gel residue on the dentin surface, it might not affect the bond strength of adhesives used in this study because the results showed that the micro-tensile bond strengths of the experimental groups were not significantly different from those of the control groups. Moreover, there was no difference in failure modes of fracture surfaces between both groups. SEM analysis might confirm the bond strength results. If topical anesthetic gel interfere bonding to dentin, the fracture surfaces may occur between dentin surfaces and bonding resin and modes of failure might different from control and experimental groups. It may be concluded that a topical anesthetic gel used (Benzo-jel) did not interfere with the bonding systems used in this study. Pictures below showed the normal dentin surface (Figure 9) compared to dentin surface covered with topical anesthetic gel (Figure 10).

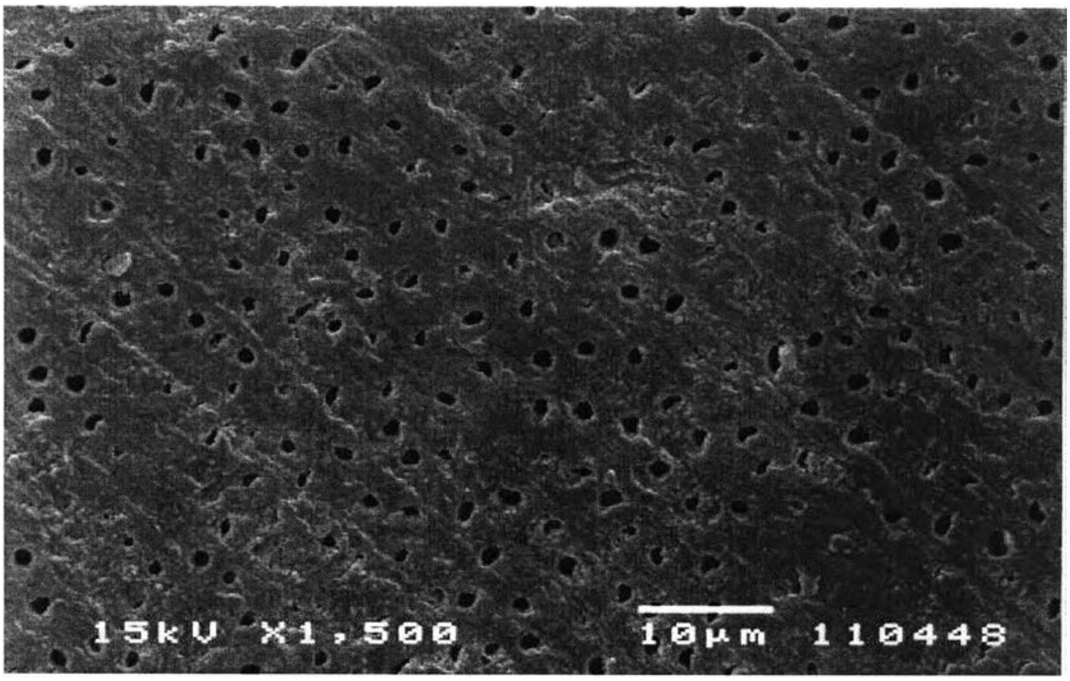

Figure 9 showed normal dentin surface under 1500x magnification level.

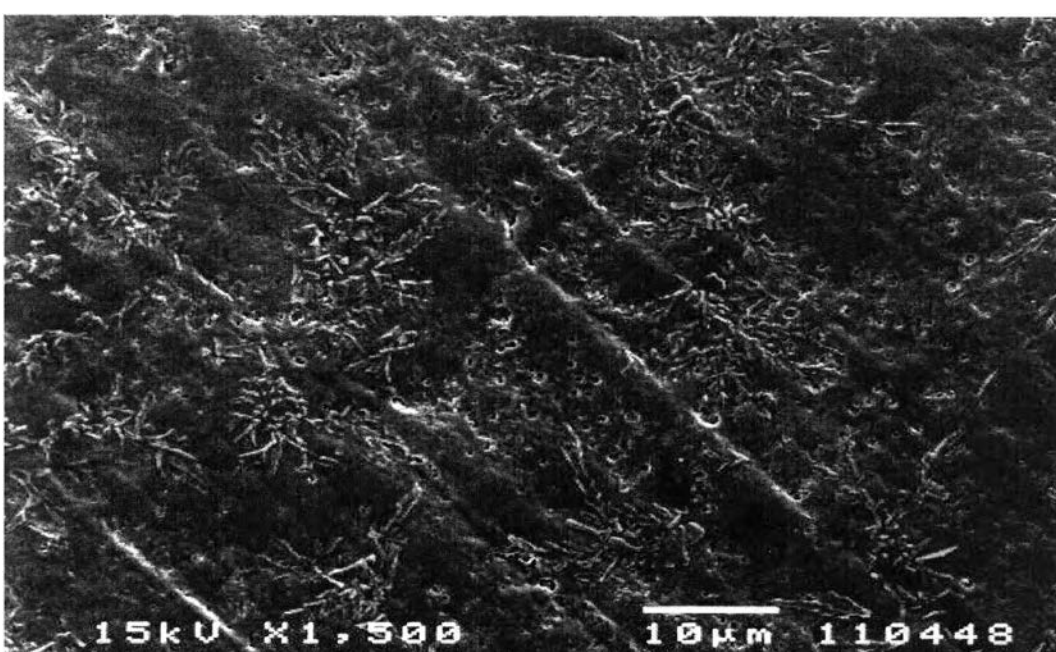

Figure 10 showed dentin surface, without rinsing with water under 1500x magnification level, was covered with topical anesthetic gel.

Benzo-jel, a 20% benzocaine gel, is a high viscosity cream at room temperature. When the gel is applied to dry oral mucosa, it remains at the application site for a longer time compared to other topical anesthetic agents (Tulga and Mutlu, 1999). Benzo-jel can dissolve in water (Gurney, 1966b). It was rinsed off with water from flat dentin surface before bonding procedures. Additionally, rinsing time in the present study might be sufficient to remove a topical anesthetic gel from the surface. Rinsing time in this study might be too long in the clinical situations. Clinically, rinsing time may be less than 30 seconds. The residue of topical anesthetic gel might adhere to the line-angles of cavities. The results might be different from this study. Therefore, further study is required to evaluate the effect of topical anesthetic gel contamination on the bond strength without rinsing with water.

Conclusion

1. The results from the present study suggest that the topical anesthetic gel (Benzo-jel) did not affect the bond strength of the adhesives used in this study after rinsing well with water.

2. The total-etch adhesive produced higher bond strength than self-etch adhesives.

3. The bond strength of all-in-one adhesive (Clearfil Tri-S Bond) was significantly not different from 2-step self-etch adhesive (Clearfil Protect Bond).

Suggestion

1. In order to achieve high bond strength, care must be taken to avoid other clinical contaminations and to remove all of the contaminants from the prepared surface prior to the application of adhesive systems. Moreover, the operator should follow the manufacturers' instructions strictly.

2. Further studies may be needed to investigate the effect of topical anesthetic gel contamination with lesser rinsing time.

3. The all-in-one adhesive system (Clearfil Tri-S Bond) can be an alternative adhesive to two-step self-etch adhesive in order to save time and decrease operator and bonding procedure variables. However, further long-term durability and clinical study may be needed to investigate the performance of newly introduced Clearfil Tri-S Bond as well as the performance of this adhesive on caries affected dentin and sclerotic dentin.