CHAPTER V

DISCUSSION

The discussion of this study is presented in three parts as follows:

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I. Discussion of the results of the study

1. Shear bond strength values

In this study, four orthodontic adhesive systems (Transbond™ XT, Transbond™ PLUS Color Change, Beauty Ortho Bond®, and Assure®) were evaluated under two surface conditions.

1.1 Non-contaminated conditions

The results indicated that the mean shear bond strength of the control group (Transbond™ XT under non-contaminated conditions), at 11.70 MPa, was significantly greater than that of the other adhesive systems, whereas in the other groups, such as Transbond™ PLUS Color Change, Beauty Ortho Bond®, and Assure®, under the same conditions demonstrated there were no significant differences in mean shear bond strength. In agreement with previous studies,[5,16,18,20,21] lower mean shear bond strength values achieved under non-contaminated conditions were found for Transbond™ PLUS Color Change, Beauty Ortho Bond®, and Assure® in comparison to Transbond™ XT (Table 1). This might be explained by the fact that the Transbond™ XT adhesive system which is a total-etching adhesive system, dissolves hydroxyapatite crystals, and enhances the penetration of resin into the etched enamel,[32] whereas, self-etching adhesive systems show more conservative etch patterns and have fewer adhesive penetrations, leading to lower bond strength.[62]

Even though both Assure® and Transbond™ XT are total-etching adhesive systems, Assure® provided significantly lower bond strength than did Transbond™ XT under non-contaminated conditions. The rationale for this lower bond strength might be that Assure® is a compomer, or polyacid modified resin composite, which

contains conventional glass ionomer cement (GIC). The physical properties of GIC have an effect on the weaker and lower strength compared with resin adhesives.[23,63,64] Therefore, a previous study suggested that compomer should be used only in clinical situations in which the material is under low stress.[53]

1.2 Artificial saliva-contaminated conditions

Saliva contamination can be a problem during direct bonding in hard-to-reach areas, for example, partially erupted teeth, posterior teeth, especially second molars, or in an extreme situation such as surgically exposed impacted teeth. Consequently, manufacturers have introduced many moisture-resistant adhesive systems into the market, such as Transbond™ PLUS Color Change, Beauty Ortho Bond® and Assure®, leading to many further studies. However, reports of shear bond strength of moisture-resistant adhesive systems in saliva contamination have produced controversial results; some have found an increase in bond strength,[1,5,18,65] and others found either no significant decrease[5,20,66] or a significant decrease in shear bond strength,[4,54] as shown in Table 2.

Under artificial saliva-contaminated conditions, Transbond™ XT, which is a coventional adhesive system, showed significantly decreased mean shear bond strength (7.24 MPa). This finding may be due in part to the loss of mechanical retention when the etched surface was contaminated. Saliva causes plugging of a biofilm over etched enamel and decreases the penetration of adhesive resins into the enamel surface.[24,67,68] This finding was consistent with those of other studies in which Transbond™ XT was bonded under saliva-contaminated conditions, resulting in reduced bond strength with statistical significance.[1-5,54] In the present study, the groups bonded with moisture-resistant adhesive systems (Transbond™ PLUS Color

Change, Beauty Ortho Bond®, and Assure®), did not show any significant decrease or increase in the shear bond strength for bonding orthodontic brackets under artificial saliva-contaminated conditions. The mean shear bond strength of all adhesive systems under artificial saliva-contaminated conditions was not significantly different. This lack of significant difference is in agreement with previous studies,[1,20,66] although some studies[4,5,54] found significant differences between conventional and moisture-resistant adhesive systems under the same conditions. An explanation for these findings might be the presence of silane coupling agents or hydrophilic monomers as a major constituent of Transbond™ PLUS Color Change, Beauty Ortho Bond®, and Assure®. The water-soluble hydrophilic monomer is an essential ingredient to promote wetting and penetration.[69] The shear bond strength of Beauty Ortho Bond® and Assure®, on the other hand, was increased under artificial saliva-contaminated conditions, but with no statistical significance, compared to that of Beauty Ortho Bond® and Assure® under non-contaminated conditions. This is in agreement with previous studies,[5,16] although some studies[4,54] found that the bond strength was reduced with statistical significance. These differences might result from the different tooth types and durations of light-curing.[4]

In the present study, artificial saliva contamination was retained for 10 seconds and blown off for five seconds, resulting in no significantly difference between shear bond strength values of total-etching adhesive systems (Transbond™ XT and Assure®) and self-etching adhesive systems (Transbond™ PLUS Color Change and Beauty Ortho Bond®). Therefore, in an attempt to save chair time and to decrease the risk of moisture contamination prior to primer application, self-etching adhesive systems containing acidic functional monomer; that demineralize the enamel

surface while simultaneously improve resin monomers penetration, could be alternative.[70]

In this study, the mean shear bond strength of all adhesive systems was greater than 6 MPa, a value suggested as adequate for most clinical orthodontic needs,[71] because it can withstand the forces of orthodontic mechanotherapy and of mastication. However, a previous report suggested that excessive bond strength over 13.5 MPa might be the cause of enamel failure.[16] Fortunately, most of the adhesive systems used in this study had shear bond strength values less than 11.5 MPa, except for some samples (which were bonded using Transbond™ XT adhesive) which had the highest bond strength at 18.10 MPa under dry conditions. Thus, orthodontists should be careful in de-bonding when Transbond™ XT is applied.

2. Sites of adhesive failure

The site of adhesive failure has been associated with many factors, such as the bracket base design and the adhesive type.[72] The tooth/adhesive interface was the most common site of adhesive failure in this study. In most samples, a greater proportion of adhesive was removed with the bracket, except for Transbond™ XT under non-contaminated conditions (control group), where most bonds failed at the bracket/adhesive interface. This result indicated that the greater amount of residual adhesives on the enamel surfaces were possibly related to the high shear bond strength of Transbond™ XT under non-contaminated conditions. Nevertheless, a controversy exists regarding the adhesive bond failure. One position is that failure at the tooth/adhesive interface is preferable to failure at the bracket/adhesive interface.

This is because such failure makes de-bonding and polishing easier than does failure at the bracket/adhesive interface.[73] Remaining adhesive on the tooth surface is undesirable because enamel damage occurrs during removal of adhesive remnants from the tooth surface, and because such removal might increase chair-side time.[72] In contrast, the other position is that the tendency to enamel fracture would increase if failure occurred at the tooth/adhesive interface; the risk is increased when increased force is needed to de-bond high strength adhesives. In order to avoid the risk of enamel fracture, bond strength should not exceed 13.5 MPa.[16] Thus, an adequate bond strength that fails at the tooth/adhesive interface would be ideal in orthodontics.[73]

II. Discussion of the materials and methods in the study

1. Tooth selection

The tooth selection in this study was aimed at minimizing the factors that might affect shear bond strength values. Besides, different buccal anatomy from different tooth types might have led to inconsistent adhesive film thickness, and consequently alter bond strength characteristics.[74] Even though a previous study suggested that the buccal surface anatomy of maxillary first and second premolars are very similar,[75] the maxillary first premolars were preferable in this study because this type of tooth is the most common human tooth type used in research[73] and is more available than other teeth. Most of them were collected after extraction for orthodontic reasons and had no defect on the buccal enamel surface.

2. Saliva

A Proline® mechanical pipette was utilized to fix the volume of saliva at 20 µl. A previous study revealed that the quality of saliva varies among individuals. The composition of saliva can differ greatly depending on the conditions under which it is produced.[76] Immunoglobulin, protein, enzymes, mucin, and nitrogeneous products make human saliva different from artificial saliva.[77] Nevertheless, artificial saliva from the Faculty of Medicine, Chiang Mai University was used in this study to control the properties and quality of saliva.

3. Brackets

The bracket is one of the important factors that affect bond strength. A previous study suggested that the bond strength depends on the optimal combination of the bracket and the adhesive.[78] The matching base design can improve adhesive penetration by increasing mechanical retention. [59]

The Mini Master Series brackets of American Orthodontics were used in the present study. The bracket base has a mono-layered mesh pattern with diagonal metal wires of size 110 µm[59] which might be the factor that made the shear bond strength values different from those of other studies.[1,4,18,20,54]

4. Force calibration

After the brackets were firmly placed on the teeth by one experienced operator, a Tension and Compression Gauge was used for calibration in order to achieve a comparable resin layer thickness.[20]

5. Shear bond strength test

Initial shear bond strengths of both light-cured and chemical-cured composite orthodontic adhesives were approximately half of the shear bond strength obtained 24 hours after the time of bonding.[73] The bond strength of adhesives increases from five minutes to 24 hours after bonding. At five minutes, bond strength was about 60 to 70 percent of the bond strength at 24 hours. The bond strength values at 24 hours and one month, and between three and six months, were insignificantly different.[73] Thus, in *in vitro* studies of mean bond strength, the time between bonding and de-bonding should not be less than 24 hours after polymerization.[73] In this study, the shear bond strength test was done more than 24 hours after polymerization, including the time for thermocycling. Clinically, archwires are usually placed a few minutes after the bonding process, when the adhesive has not reached its maximum bond strength; therefore care should be taken in clinical practice.

6. Temperature change

Routine behaviors of the oral cavity allow temperature change, such as drinking, eating and breathing, resulting in thermal stress. Thermal stresses result in mechanical stresses and induce cracks through the bonded interface, thus changing gap dimension.[56] Thermocycling is a widely used artificial aging technique and simulates the oral environment. As indicated by ISO TR 11450 Standard (1994) that a thermocycling regimen in water at 5-55°C is an appropriate artificial ageing test, several studies have been conducted following this protocol. Studies about the number of thermal cycles are controversial. A previous study suggested that there was a significantly reduced mean bond strength of a self-etching primer after 2,000

thermal cycles.[57] Therefore, in this study only 2,000 thermal cycles were performed, and the results of all groups showed acceptable shear bond strength values.

7. Limitations of the research

7.1 *In vitro* study

An *in vitro* study cannot be directly related to the clinical situation, as in the oral cavity conditions, such as the aging of resin materials, intraoral temperature changes, and stress from mastication are more complex than can be replicated by thermocycling alone..[35] In clinical situations, moreover, the combination of shear, tensile, and compressive force systems usually occurs, whereas this study was capable of producing only shear de-bonding force.

7.2 Artificial saliva

The artificial saliva used in this study might have had a different formulation from that used in other studies.

III. Clinical implications

All adhesive systems in this study are able to use in both non-contaminated and artificial saliva-contaminated conditions. Nevertheless, it should be realized that non-contaminated situation is more prefer in clinical implication.