CHAPTER V

DISCUSSION

The discussion is presented in two parts as follows:

I. The method of the study

II. The results of the study

I. The method of the study

Tooth type and enamel surface

Extreme variety exists in the type of tooth selected for bond strength testing, from human teeth (including molars, incisors, and premolars) to animal (bovine) teeth. Bovine teeth have been used due to the limited availability of human teeth and the increased awareness of infection hazard from human teeth. The current assumption is that orthodontic brackets bonded to bovine enamel will perform in the same way as they do to human enamel. Barkmeier and Erickson found that the enamel bond to bovine teeth is significantly weaker than to human teeth. The results of this study are similar those of Oesterle *et al.*,[55] who found that the strength of the bond to bovine enamel is lower than to human enamel. They suggested that this reduced bond strength is because of the differences in formation between bovine and human enamel, and the larger crystal grains and the greater number of lattice defects than in human enamel.

Human incisor teeth have been used in some studies. However, extraction of incisors as part of orthodontic treatment is relatively uncommon. It is likely that enamel changes with age, including its surface fluoride content. The majority of study used the surface enamel of human premolar teeth, extracted from young patients for orthodontic reasons. In the absence of evidence that different enamel types do not affect orthodontic bond strength, it would seem preferable to use premolars.[56]

Storage medium between bonding and testing

A wide variety of storage media is used between bonding and testing, yet no investigations into the effects of different media on bond strength have been performed. Despite a wide variation in times between bonding and testing, very few studies have investigated this parameter. Nagel tested specimens at 24 hours and 1 month. He concluded there was no deterioration in bond strength. Reynolds and von Fraunhofer tested specimens at intervals between 3 hours and 6 months. They stated that the bond strength did not vary significantly. Tavas and Watts[56] investigated light- and chemical-cured materials. They concluded that bond strength increased over time from 5 minutes to 24 hours, the 5-minute values being about 60-70 percent of the 24-hour values suggesting that the timing between bonding and testing is probably not critical, as long as this period is not less than 24 hours.

With respect to the immersion media, saline has been shown to soften enamel more than does distilled water. Most studies of adhesion to enamel are carried out using distilled water. The effect of temperature has never been investigated in orthodontic bond strength testing, but the majority of studies refer to the use of water at 37°C for 24 hours. In the absence of any evidence that this adversely affects bond strength, it is suggested that this should be the medium used in all studies.[56]

Thermocycling

Orthodontic adhesives are routinely subjected to thermal changes in the oral cavity.[57] Air temperature, humidity, and air velocity when breathing can also alter resting mouth temperature. Although these variations are erratic and hard to anticipate when testing, it is important to determine whether these temperature variations introduce stresses in the adhesive that might influence its bond strength. Therefore, Bishare *et al*.[58] have suggested that thermal cycling should be part of the testing protocol for adhesives. They should be tested both at 24 hours after bonding and after thermal cycling.

It has been reported that after thermocycling, there was a reduction in the mean shear bond strength for no-mix adhesive.[(58)] The decrease in the bond strength of thermally cycled specimens relative to those that were not cycled may possibly be explained by the absorption of water and the alternating stressing of the system resulting from the large mismatch of the thermal expansion coefficient of the adhesives with those of the stainless steel bracket and enamel. These differences between the thermal coefficients of three components of the system are likely to adversely affect the adhesion of the resin to other parts of the system.[59]

Saito *et al*.[60] showed that the durability of the bonding of orthodontic brackets to enamel using Superbond C&B was influenced by the method of enamel pretreatment, i.e., phosphoric acid etching or self-etching primer treatment. Phosphoric acid etching significantly decreased the bond strength after thermocycling. The results of this study are consistent with those of Miwa *et al*.[61] and of Hayakawa and Nemoto[62] suggested that the reason for the decrease in the bond strength after thermal cycles was the deterioration of the physical properties of Superbond C&B.

Shear bond strength testing

The majority of studies report the use of an Instron testing machine or an equivalent. The majority of studies report the use of a steel loop around the bracket to connect it to the machine. It is suggested that if a steel loop is used to apply the de-bonding force to the bracket slot so that the point of application is at the same distance from the bracket/resin interface in all case, the method of testing is more reproducible.[56]

II. The results of the study

Shear bond strength

In this study, the mean shear bond strength values of normal teeth ranged from 10.25 to 13.86 MPa, those of fluorotic teeth ranged from 6.51 to 12.29 MPa. The findings demonstrate that fluorotic teeth significantly reduced the shear bond strength of brackets bonded to enamel. This effect may be due to the acid-resistant outer layer of the fluorosed enamel.[42] Fluorotic teeth have the highest concentration of fluoride in the outer 200 µm of enamel. The concentration of fluoride in this region increases with increasing Thylstrup and Fejerskov's (TF) score.[33] The hypermineralized surface layer of fluorotic enamel is difficult to etch, resulting in less irregularity of the enamel surface after enamel etching than in normal enamel.[7,34,35]

Our findings are consistent with those of Adanir *et al.*[41,42] and Gungor *et al.*, [62] who reported that fluorotic teeth significantly decreased the bond strength of orthodontic brackets. However, the bond strength with fluorotic teeth is more than the minimum 6 to 8 MPa that is sufficient for clinical orthodontic bonding.[41,42,63] Ertugrul *et al*.[64] studied shear bond strength using three different bonding strategies with normal and moderately fluorotic enamel. They found that the bonding effectiveness to enamel was lower in fluorotic teeth than in normal teeth for all the adhesives tested. Opinya and Pameiger[8] studied tensile bond strength in teeth with moderate and severe dental fluorosis and found that the tensile bond strength in teeth with dental fluorosis was less than in normal teeth. Besides, another report showed that routine acid etching of fluorotic teeth produced shear bond strength that was less sufficient than was required for clinical orthodontic bonding.[40] Weerasinghe *et al.*[64] reported that the degree of fluorosis in fluorotic teeth affected the micro-shear bond strength of a self-etching bonding system to fluorosed enamel, and Shida *et al.*[36] reported that fluorotic teeth demonstrated significantly lower bond strength values than did normal teeth.[36,65] Ermis *et al*.[66] found that the micro-shear bond strength of fluorotic teeth was significantly lower than that of normal teeth.

In contrast to the present study, Na'ang'a *et al.*[38] studied tensile bond strength in teeth with mild to moderate dental fluorosis. Their study found that fluorotic teeth decreased the bond strength compared with normal teeth. However, there was no significant difference in mean bond strength between fluorotic and normal teeth. Ateyah and Akapata[39] reported that the degree of fluorotic teeth had no significant effect on shear bond strength of composite resin bonded to enamel. These findings are consistent with those of Ratnaweera *et al*., [67] who reported that micro-shear bond strength was not affected by the degree of fluorosis.

The mean shear bond strength values of Superbond C&B were significantly greater than those of System^{TM} 1^{+} and Unite^{TM} on both normal and fluorotic teeth. System^{TM} 1^{+} and Unite^{TM} are chemically cured nomix orthodontic adhesives. Superbond C&B is a resin cement. It is reported that the variation of the concentration of phosphoric acid from 20% (wt) to 65% (wt) did not produce different bond strength between 4-META/MMA-TBB resin and etched enamel, although demineralization decreased with increasing concentration of phosphoric acid. Thus, manufactures recommend pre-etching the enamel surface with 65% (wt) phosphoric acid for tight adhesion of the 4-META/MMA-TBB resin to enamel in order to minimize the enamel loss.[68] The increase bond strength values achieved with Superbond C&B were most likely a result of its being an unfilled acrylic material containing 4-methacryloxyethyl trimellitate anhydride (4-META) monomer. 4-META is a difunctional monomer presenting a hydrophobic methacrylate group and a hydrophilic aromatic anhydride group. Functionally, the hydrophobic methacrylate group is able to combine with resins in composite/acrylic adhesives, while the hydrophilic aromatic anhydride group is able to promote adhesion to the tooth surface. Tri-*n*-Butyl borane (TBB) initiates the graft polymerization methyl-methacrylate (MMA) in to the tooth substrates, and good adhesion to the tooth is, therefore, obtained.[69] It is thought that increased bond strength is achieved through the ability of 4-META to enhance diffusion into enamel.[50]

In fluorotic teeth, the mean shear bond strength values of System™ 1+ and Unite™ were within the range of adequate clinical values (6-8 MPa), but that of Superbond C&B was greater than 6-8 MPa. However, several samples of System ™ 1+ and Unite™ produced shear bond strength values less than adequate clinical values, whereas only one sample of Superbond C&B produced shear bond strength value less than adequate clinical values. So, this study recommends Superbond C&B for clinical use in orthodontic placement of brackets on fluorotic teeth.

Adhesive Remnant Index score

Of primary concern to the clinician is the maintenance of a sound, unblemished enamel surface after removal of the bracket, yet bracket failure at each of these two interfaces has its own advantages and disadvantages. As an example, bracket failure at the bracket/adhesive interface is advantageous because it leaves the enamel surface relatively intact. However, considerable chair time is needed to remove the residual adhesive, with the added possibility of damaging the enamel surface during the removal process. Conversely, when brackets fail at the enamel/adhesive interface, less residual adhesive remains, but the enamel surface can be damaged when failure occurs in this mode.[70] The ARI scores indicated that brackets bonded with either system showed a similar range of bond failure modes. In normal teeth, the commonest site of failure for System™ 1+ was with adhesive and cohesive failures at the enamel/adhesive interface. For Unit™, sites of failure were found with adhesive and cohesive failures at the enamel/adhesive interface as well as with adhesive and cohesive failures at the adhesive/bracket interface. The commonest site of failure for Superbond C&B was found at the adhesive/bracket interface. In fluorotic teeth, the commonest site of failure for System™ 1+ and Unite™ were found with adhesive and cohesive failures at the enamel/adhesive interface. The commonest site of failure for Superbond C&B was found at the adhesive/bracket interface.

Further studies

1. Evaluate the etched enamel pattern of fluorotic teeth by scanning electron microscopy
2. Determine the amount of enamel loss during enamel clean-up after removal of residual adhesives.
3. Microstructure evaluation of fluorosed enamel under scanning electron microscopy should be done to obtain derived data that might be more meaningful than was possible in this study.