A better understanding of orthodontic bracket bonding

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CHAPTER 9

Summary and conclusions

Chapter 1 describes briefly the history of orthodontics, the development of resin composite and its use in orthodontics. In 1965 for the first time the direct bonding technique for orthodontic purposes was described. Since then testing of orthodontic cements led to more than 500 scientific articles up to the present date. In this chapter the different *in vitro* tests are described. Furthermore, the factors that possibly influence these tests are described. The search for improvements and alternatives resulted in the resin based materials that are used nowadays, glass ionomer cement being the most obvious alternative. The aim of this thesis is to provide a better understanding of the bonding quality of orthodontic brackets to enamel in general and with glass ionomer cements in particular.

In **chapter 2** for Transbond XT (one of the most frequent used light curing resin composite bonding agents) the current literature is reviewed. The bond strength itself, bond strength in relation to time, the influence of possible external variables on the bond strength, such as speed of the tensilometer during testing and type of enamel is evaluated. After application of the in- and exclusion criteria to the systematically searched articles 61 publications remained. Conclusions drawn from the results of the selected literature are that the average bond strength measured is between 9.3 - 15.4 MPa and the material being fully cured after 24 hours. The type of enamel and crosshead speed do not seem to influence the bond strength significantly.

In earlier presented papers a positive effect of the application of ultrasound to curing cement is described. Therefore in **chapter 3** the influence of ultrasound on bracket bonding with glass ionomer cement is evaluated. Three glass ionomer cement-based materials are used, Fuji Ortho LC, Fuji IX Fast and Fuji Plus. The brackets are bonded with these cements and cured respectively with ultrasound, heat, or according to the manufacturer's instructions. After 15 minutes the specimens are fractured in tensile mode. The results show that heat curing has an effect on all groups while ultrasound application only benefits the resin modified glass ionomer cements, Fuji Ortho LC and Fuji Plus. It is concluded that accelerating the setting still not results in bond strength values that can compete with composite materials after 15 minutes setting. These findings result in questions concerning the working mechanism of the accelerated setting and the ideal setting environment for glass ionomer cements.

It is clear that temperature plays an important role in setting glass ionomer cements. The susceptibility to water absorption is also assumed to be essential. These two properties, the influence of temperature and storage medium on the setting cement, are researched in **chapter 4**. Two conventional glass ionomer cements, Fuji IX Fast and Ketac Molar, are used. In the first part of the research the working and setting times are determined using a Wilson's rheometer at different temperatures. For the second part of the research cylindrical specimens are prepared. These specimens are stored for different time periods, in different media, oil or water, and at different temperatures. The compressive strength of these specimens is measured. The results show that a temperature between 60 °C and 70 °C, applied during setting, gives a significant higher initial compressive strength and reaction speed, resulting in an almost "on command" curing for both materials. The storing temperature, time, and medium has a significant influence on the compressive strength of Ketac Molar and Fuji IX Fast. This should be taken into consideration when using these materials either in the clinic or for research purposes.

In **chapter 5** the influence of different bracket base treatments on the bond strength and the location of fracture (ARI score) is investigated. According to literature most of the bracket failure takes place within the cement or between the bracket and the cement. This indicates that the bracket-cement interface is the weakest part of the bracket-cement-enamel system. The hypothesis therefore is that altering the base might have a positive influence on the tensile and shear bond strength. Next to the control group three bracket base pre-treatments are performed: sandblasting, tinplating, and silicoating the base. The results do not show a clear positive effect in any of the base pre-treatments.

To quantify the variation in bond strength of the different components of the bracket-cement-enamel system shear tests are performed on these components and described in **chapter 6**. The complete bracket-cement-enamel system is used as a control. Not only the initial strength is determined, but also the influence of repeated mechanical loading. The shear strength fatigue limit shows a similar pattern for all three cements. The bracket-cement bond gives the highest results while the bracket-cement-enamel system showed the weakest results for two of the three cements. This is remarkable taking into account that most failures take place within the cement or between the cement and the bracket. A repeated mechanical loading of 10,000 cycles on the specimens gives an average strength reduction of 50%.

In **chapter 7** the influence of shear loading the long and short sides of the bracket is investigated. Furthermore the stresses present at fracture are analysed with scanning electronic microscopy (SEM) and rationalized with models calculated with finite element analysis (FEA). The results show that the shear strength of identical brackets, loaded at the long as well as at the short side, differed. There are several possible explanations for these results. It is most likely that the angle of loading plays a key role. When the load application is not completely perpendicular to the base, not only a shear force is applied, but also a compressive force. The resistance against compression is higher then against shear loading. It is concluded that because of the non-homogeneity of the stress distribution during these shear tests and the difficulty in controlling the test variables, bond strength testing can best be performed in a tensile mode.

Conclusions

In conclusion, the present study shows in detail the complexity of a seemingly simple problem, the adhesion of a bracket to a tooth. According to the literature Transbond XT is a clinical well performing orthodontic composite-based cement with an average *in vitro* shear bond strength of 9.3- 15.4 MPa. Based on experimental work described in this thesis, *in vitro* experiments show that the bond strength of Transbond XT, Fuji IX Fast and Fuji Ortho LC to enamel is significantly reduced by fatigue. Heat application and curing in a water-free surrounding improves the strength of conventional glass ionomer cement significantly. An “on command” setting can be achieved with the application of sufficient heat. Accelerated setting by means of heat or ultrasound results in significantly higher tensile bond strengths for glass ionomer cements. Still, it is not recommended to use these materials for bracket bonding because of the inappropriate bond strength.

Models calculated with Finite Element Analysis show that none of the applied loading directions on a bracket-cement-enamel system result in a homogeneous stress distribution within the cement layer. Therefore bond strengths in Pascal as well as load to failure in Newton should be discussed. In this view performance of tensile tests instead of shear tests is recommended. To improve the bond strength, alteration of the elasticity of the different components of the bracket-cement-enamel system might be more successful than searching for improvement of the weakest link determined by the adhesive remnant index.