**<u>Shear bond strength: An *in vitro* comparison of three resin adhesives and a maxillary molar bracket.</u>**

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Transbond XT and Enlight adhesive resins are widely used and have been proven to be clinically successful adhesives. Transbond XT adhesive resin is widely referred to in the literature as a benchmark material to which other materials are often compared (Sato and Yasuda 2007, Bishara *et al* 1997, 1999a, 1999b, 2004b, 2005). The first objective of this study was to assess whether the new adhesive (Sure Ortho Light Bond) was comparable to two other adhesives already available in the marketplace.

Stratman *et al* (1996) demonstrated consistent microscopic enamel damage in cases of the debonding fracture occurring at the adhesive/enamel interface. Retief 1974 demonstrated *in vitro* enamel fracture at 9.7 MPa. Enamel fracture on debonding metal brackets is an occurrence that is not commonly associated with the clinical situation (Summers *et al* 2004, Pickett *et al* 2001, Banks and Macfarlane 2007). Rix *et al* (2001) state that it is well documented that laboratory testing procedures provide higher bond strengths than obtained in the clinical situation, because of the etch pattern achieved. Banks and Macfarlane (2007) confirmed that *in vivo* bond strengths were lower than *in vitro* results. This is thought to be as a result of the possibility of moisture contamination, access and inter-operator differences in the clinical arena. These instances of enamel damage could have occurred as a result of the etch pattern achieved on these 23 teeth. The fractures could also have occurred as a result of the variable hardness characteristics of surface enamel which have been found to vary by 15% from one random location to another according to S. R. Grobler (personal communication October 2007).

## <u>Methodology</u>

The aim of this study was to comparatively assess the shear bond strength of three resin based adhesives. This was achieved by using the three adhesive resins in conjunction with a bondable maxillary molar bracket and comparing the shear bond strengths of each combination.

The three light cured adhesive resins used to bond the brackets were Transbond XT (3M Unitek, Monrovia, CA 91016. U.S.A.), Enlight (Ormco, Orange, CA92867. U.S.A.) and Sure Ortho Light Bond (Sure Orthodontics, Geneva. Switzerland).

Sixty maxillary molar stainless steel orthodontic brackets were obtained. Victory Series (3M Unitek, Monrovia, CA 91016. U.S.A.) Lot 998186100 were used.

Forty eight upper extracted human molar enamel specimens were selected according to a selection protocol. Teeth with caries affecting or undermining the buccal enamel were excluded. As were teeth exhibiting fluorosis or enamel damage as result of the extraction process. The enamel was inspected at ten times magnification for any signs of enamel damage.

The selected teeth were prepared for bonding and were sectioned in such a way as to remove the roots this was done by means of a water cooled high speed turbine handpiece. The sectioned crowns were stored in water at four degrees centigrade with a few crystals of thymol added (as an anti-bacterial agent). The teeth were randomly assigned to three groups of sixteen teeth each. Each group was bottled and labeled with the assigned bracket/adhesive resin combination. This was done with a view to ensure that sixteen brackets would be bonded with the each of the three adhesive agents. Each enamel specimen was then checked in order to identify any unacceptable morphology of the buccal surface of any of the enamel specimens. This was done by placing an example of the bracket with its base positioned in the prescribed position on the buccal enamel. If there was any doubt regarding the closeness of the 'fit' of the base to the tooth, the tooth was excluded from any further testing and another specimen was assessed and used if found to be suitable. This was done in an attempt to minimise the variation of the thickness of the adhesive layer as much as possible.

All the enamel specimens were gently polished (for 10 seconds) with a oil free, fluoride free pumice solution to clean the enamel thus simulating the removal the pellicle as in the clinical scenario.

All the brackets were bonded in one session by the same operator. Each of the three adhesive resins was used in accordance with the instructions of their manufacturer. The bracket was positioned on the buccal surface of each tooth, by means of bracket tweezers, and then a force of four hundred grams was applied by means of a Dontrix gauge (American Orthodontics, Sheboygan, Wisconsin, WI53081. U.S.A.) in order to ensure a consistently close fit between the bracket base and enamel surface, as well as maximal penetration of adhesive into the mesh design of the bracket base. Prior to light curing the excess adhesive agent was removed from around the base of the bracket with a sharp probe.

The adhesive resin on each bonded tooth was light cured for thirty seconds (10 seconds from a mesial direction, 10 seconds from an occlusal direction and 10 seconds from distal of the bracket) with the exit portal of the light curing as close as possible to the bracket. A standard standard tungsten quartz halogen curing light (Optilux 501, Demetron Research Corporation) was used to cure the bonding agents. A light intensity range of between 440 and 480 $mW/cm^2$ was used. The intensity of the curing light was checked after every 8 exposures with a Dentsply light intensity meter (Cure Rite Meter, Dentsply, Caulk.) to ensure this consistent intensity. Each bonded specimen was placed back into the water/thymol solution in its designated bottle and stored for twenty four hours at room temperature and the exposed to a temperature cycling procedure. This entailed each specimen being exposed to 500 cycles of heat and cold. The specimens were exposed to a temperature high of $55^{o}$ C as opposed to a low of $5^{o}$ C, in cycles of 15 seconds with a dwell time of 30 seconds (Saayman *et al* 2005, Grobler *et al* 2007a).

Following the temperature cycling the enamel specimens were stored in their respective adhesive/bracket combination groups. The bonded enamel specimens were then embedded in plastic cups with cold curing acrylic resin. The specimens were positioned by means of a jig in such a way that the entire buccal enamel surface stood proud of the embedding material and the plastic cup in such a way that the bracket/enamel interface was positioned at ninety degrees to the long axis of the plastic cup.

The specimens were clamped to the base of the Zwick Universal testing machine (Matterialprufung, 1446, Germany). A shear load was applied in an occluso-gingival direction to the attachment, with the debonding force parallel to the bracket/adhesive interface. This load was applied by means of a knife-edged rod at a crosshead speed of 0.5 mm per minute. Shear bond strengths were registered in Newtons to be converted and expressed in mega pascals (MPa).

The bracket contact surface area was measured making use of a reflex microscope (Prior S2000 Reflex Microscope, 9 Whitehall Park, London. N19. No 001).

## Results

The results after debonding were compared (tables 4.2b and 4.3a). The average shear bond strength for the adhesives used with this bracket ranged from a low of 9.2 MPa (242.2 Newtons) when combined with Enlight adhesive resin to a high of 11.7 MPa (306.1 Newtons) when combined with Sure Ortho Light Bond adhesive resin. The standard deviation in the shear bond strength displayed in the three groups varied but not significantly.

The GAC bracket/Enlight adhesive resin combination displayed the lowest average shear bond strength of the three adhesive resins in this group (9.2 MPa), similar to the value achieved in combination with the 3M brackets (9.8 MPa). The average and the minimum shear bond strengths of this combination were the lowest in the group (tables 4.2b and 4.3a). The lowest shear bond strength value of 4.3 MPa (112.3 Newtons) ranged to a maximum of 13.6 MPa (357.2 Newtons) with an average value of 9.2 MPa (242.4 Newtons). This combination showed the largest range within the group with a standard deviation of 2.6 MPa (67.3 Newtons).

The GAC bracket/Sure Ortho Light Bond adhesive resin combination displayed the highest average shear bond strength, as well as the highest maximum and the highest minimum reading in the group (tables 4.2b, 4.3a and figures 4.2a, 4.3a). A minimum shear bond strength of 9.3 MPa (244.8 Newtons) was achieved, this ranged to a maximum of 14.6 MPa (382.9 Newtons) with an average of 11.7 MPa (306.1 Newtons). Sure Ortho Light Bond displayed the lowest standard deviation 1.6 MPa (43.0 Newtons) in the group.

The GAC bracket/Transbond XT adhesive resin combination displayed an average shear bond strength of 10.4 MPa (272.6 Newtons). A minimum shear bond strength of 4 MPa (104.2 Newtons) was the lowest in the group. A maximum shearbond strength of 12.7 MPa (333.9 Newtons) was registered and was the lowest maximum in the group. The standard deviation was 2.1 MPa (54.5 Newtons) (tables 4.2b and 4.3a).

According to the Kruskal-Wallis multiple comparison test (tables 4.2.1c and 4.3.1c), the z-value of the GAC bracket/Sure Ortho Light Bond adhesive resin combination and the GAC bracket/Enlight adhesive resin combination were significantly different. The Regular test shows the medians to be significantly different if the z-value is greater than 1.9600. The z-value comparative of these two combinations was 2.352 using MPa values and 2.2164 using Newton values.

The Tukey-Kramer multiple comparison test using MPa values (figure 4.3.1a) confirmed this, while the Tukey-Kramer multiple comparison test for the Newton values (figure 4.2.1a) did not confirm this significant difference.

Of interest in this group was the fact that the minimum shear bond strength of the GAC bracket/Sure Ortho Light Bond combination was found to be more than double that of the other two combinations. A shear bond strength of 9.3 MPa (244.8 Newtons) was registered as opposed to 4.3 MPa (112.3 Newtons) for the GAC bracket/Enlight resin combination and 3.98 MPa (104.2 Newtons) for the GAC bracket/Transbond XT combination. Displaying the type of advantage expected by the manufacturer and experienced by the official tester (in this part of the study)

Sure Ortho Light Bond average shear bond strength was marginally the highest in this group but did not display the type of advantage as expected by the manufacturer or experienced by the official tester (in this part of the study) when compared to the average shear bond strength of either Transbond XT or Enlight.

In this range of tests Sure Ortho Light Bond produced average shear bond strengths consistently higher than that of Enlight with all three bracket combinations (tables 4.2b and 4.3a). Using the Regular test associated with the Kruskal-Wallis multiple comparison z-value test the GAC bracket/Sure Ortho Light Bond adhesive resin combination was significantly stronger than the GAC bracket/Enlight adhesive resin with a z-value of 2,352 (table 4.3.1c), this significance is however not strong enough to be confirmed by the Bonferroni test.

The GAC bracket/Sure Ortho Light Bond adhesive resin combination displayed an average rank, median and mean values higher than that of the GAC bracket/Transbond XT adhesive resin (tables 4.2.1b and 4.3.1b).

The 3M bracket/Transbond XT adhesive resin combination produced a higher median value than the GAC bracket/Sure Ortho Light Bond adhesive resin combination (Tables 4.2.1b and 4.3.1b).

There was no statistically significant difference found between Transbond XT and Sure Ortho Light Bond in association with any of the brackets used in the tests (figure 4.2a and 4.3a). When compared to Transbond XT the shear bond strength of Sure Ortho Light Bond did not live up to the higher shear bond strength expectations of its manufacturer. The manufacturer claims that because of the 4-META in the product it should return bond strengths 1.5 times that of competitors containing conventional bis-GMA because of enhanced mechanical and chemical bonding with both the enamel and the metal surface (Zalsman 1st April 2007, Sato and Yasuda 2007).

When Sure Ortho Light Bond and Enlight adhesive resins are compared, the Sure Ortho Light Bond shows higher average shear bond strengths.  In combination with the GAC bracket the difference is significant (Table 4.2.1c and 4.3.1c).  This confirms the higher shear bond strength expectations of the manufacturer (Zalsman 1st April 2007), and the findings in the official test results (Sato and Yasuda 2007).