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In vitro evaluation of shear bond strengths of colour change adhesives

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SUMMARY The aims of this study were to test whether the shear bond strengths (SBS) of three commercially available colour change adhesives (CCAs), Transbond Plus Color Change Adhesive, Grēngloo, and Blūgloo, are different and to compare their bond strengths with a traditional light cure adhesive, Light Bond.

Forty-eight human permanent premolar teeth extracted for orthodontic reasons and without any caries or visible defects were used in this study. The brackets were bonded with Light Bond (group I), Grēngloo (group II), Blūgloo (group III), and Transbond Plus CCA (group IV). After bonding, the SBS of the brackets were tested with a Universal testing machine.

Analysis of variance indicated a significant difference between groups I and IV ($P < 0.001$). No significant difference was found between groups II, III, and IV ($P > 0.05$). Adhesive remnant index (ARI) scores for all groups were not significantly different ($P > 0.05$).

Significant difference existed between the SBS of Transbond Plus CCA and Light Bond. Although Transbond Plus CCA yielded the lowest SBS values, no statistically significant difference was found between bond strength values of the three commercially available CCAs. All three CCAs can be safely used in orthodontic practice since they yielded acceptable bond strengths. A higher incidence of ARI scores 4 and 5 revealed that bond failures in all test groups were mainly at the adhesive interface.

Introduction

Prior to the 1970s, orthodontic brackets were attached to teeth by stainless steel bands. This bonding technique was painful and time-consuming. The enamel beneath the bands was more prone to pre-carious lesions during treatment. Later, in the 1970s, it became possible to directly bond orthodontic appliances to an etched tooth surface with self-curing polymeric resinous adhesives.

While there has been progress in the formulation of orthodontic adhesives, there is a continuing need for orthodontic adhesives, which have low polymerization shrinkage and high physical properties, together with features that make the bonding procedure easier. The latest products in this field are colour change adhesives (CCAs). Besides their physical properties, the major advantage of these products is that any adhesive remnant is visible at bracket seating; facilitating flash clean-up. The manufacturers also claim that the CCA Grēngloo (Ormco Corp., Glendora, California, USA) was designed with a patented ingredient that increases traumatic impact resistance by 118 per cent.

Recently, a number of studies (Chalgren *et al.*, 2007; Northrup *et al.*, 2007; Lowder *et al.*, 2008) compared the bond strengths of CCA with light cure adhesives. However, to date, no scientific research has compared the shear bond strengths (SBS) of different CCA within themselves and with a traditional light cure adhesive.

The aims of this study were to test whether the SBS of three commercially CCA, Transbond Plus CCA (3M Unitek, Monrovia, California, USA), Grēngloo, and Blūgloo (Ormco Corp.), are different, and to compare their bond strengths with a traditional light cure adhesive, Light Bond (Reliance Orthodontic Products, Itasca, Illinois, USA). The null hypothesis tested was that no difference existed between the SBS of CCA and traditional light cure adhesives.

Materials and methods

Forty-eight human permanent premolar teeth extracted for orthodontic reasons and without any caries or visible defects were used in this study. Each tooth was individually embedded in auto-polymerizing acrylic resin (Meliodent; Heraeus Kulzer, Hanau, Germany). The specimens were kept in distilled water at room temperature except during the bonding and testing procedures. Before bonding, the facial surfaces of the teeth were cleaned with a mixture of water and pumice. The teeth were rinsed thoroughly with water and dried with oil and moisture-free compressed air. Each tooth was etched with 37 per cent phosphoric

acid gel (Gel Etch®, 3M Unitek) for 30 seconds, rinsed with a water/spray combination for 30 seconds, and dried until a characteristic frosty white etched area was observed. Ormco Mini 2000 (Ormco Corp.) premolar metal brackets were used. The surface area measured and calculated with a digital calliper was 9.63 mm^2. The minimum sample size for 0.75 power of the study was statistically calculated as 12; therefore, 48 teeth were divided into four equal groups.

Group I: a thin uniform coating of Light Bond Primer was applied to each tooth surface to be bonded using the disposable brush. A small amount of Light Bond adhesive paste was applied to the bracket base.

Group II: the brackets were bonded with Ortho Solo Primer (Ormco Corp.) and Grēngloo adhesive paste.

Group III: the brackets were bonded with Ortho Solo Primer and Blūgloo adhesive paste.

Group IV: the brackets were bonded with Transbond XT Primer (3M Unitek) and Transbond Plus CCA.

Immediately after application of the adhesive, the brackets were lightly placed onto the tooth surface and pressed firmly. Excess adhesive around appliance bases was gently removed with a sharp scaler and cured with a Heliolux DLX (Vivadent ETS, Schaan, Liechtenstein) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surfaces of the brackets). After each curing, the light source was calibrated.

All specimens were stored in distilled water at 37°C for 24 hours. Each specimen was loaded into a Universal Testing Machine (Lloyd, Fareham, Hampshire, UK) using Nexjen (Charlotte, North Carolina, USA) software for testing, with the long axis of the specimen perpendicular to the direction of the applied force. The standard knife-edge was positioned to make contact with the bracket base. Bond strength was determined in shear mode at a crosshead speed of 0.5 mm/minute until fracture occurred. Failure load values (N) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base (9.63 mm^2).

After debonding, all teeth and brackets in the test groups were viewed using a light stereomicroscope (Olympus SZ 6045 TR Zoomstereomicroscope, Olympus Optical Co, Osaka, Japan) at ×10 magnification to determine the bracket failure interface. Any adhesive remaining after debonding was assessed and scored according to the modified adhesive remnant index (ARI; Olsen *et al.*, 1997). The scoring criteria of the index are as follows: 1 = all of the composite, with an impression of the bracket base remains on the tooth; 2 = more than 90 per cent of the composite remains on the tooth; 3 = more than 10 per cent but less than 90 per cent of the composite remains on the tooth; 4 = less than 10 per cent of composite remains on the tooth; and 5 = no composite remains on the tooth.

Statistical analysis

Descriptive statistics, including the mean, standard deviation, minimum, and maximum values, were calculated for each of the tested groups. One-way analysis of variance (ANOVA) and Tukey multiple comparison tests were used to compare the SBS of the groups. The chi-square test was used to determine significant differences in ARI scores among the groups. Significance for all statistical tests was predetermined at $P < 0.05$. All statistic analysis was performed using the Statistical Package for Social Science version 11.0 (SPSS Inc., Chicago, Illinois, USA).

Results

The descriptive statistics for the SBS (MPa) of the groups are shown in Figure 1. All groups displayed clinically acceptable mean bond strengths (over 8 MPa). ANOVA indicated a significant difference between groups I and IV ($P < 0.001$; Table 1). No significant difference was found between groups II, III, and IV ($P > 0.05$).

Frequency distribution of the ARI scores and the chi-square comparison of the groups are presented in Table 2. There was no significant difference between the groups ($P > 0.05$).

Discussion

The minimum bond strength required to withstand normal orthodontic forces is believed to be between 6 and 8 MPa (Reynolds, 1975). In the present study, the SBS of the test groups ranged from 7.9 to 26.1 MPa, while the lowest values (mean = 16.0 MPa) were obtained when brackets were bonded with Transbond Plus CCA.

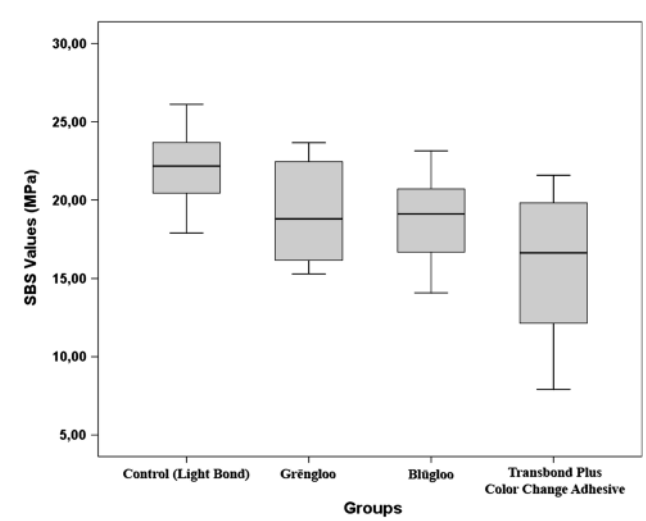

Figure 1 Shear bond strengths (MPa) of the groups. The horizontal line in the middle of each boxplot shows the median value; horizontal lines in box indicate 25 and 75 per cent quartiles; lines outside the box indicate 5 and 95 per cent quartiles.

Table 1 Analysis of variance comparing the shear bond strength (SBS) of the groups.

Test groups	SBS (in MPa)	
	Mean ± SD	Range
Group I (control–light bond)	22.1 ± 2.5[a]	17.9–26.1
Group II (Grēngloo)	19.2 ± 3.3[a,b]	15.3–23.7
Group III (Blūgloo)	18.7 ± 2.8[a,b]	14.1–23.1
Group IV (Transbond Plus Color Change Adhesive)	16.0 ± 4.4[b]	7.9–21.6

There was no statistically significant difference between groups with the same letters ($P > 0.05$).

Table 2 Frequency distribution of the adhesive remnant index (ARI) scores and chi-square comparison of the groups.

Test groups	ARI scores					*n*	Test
	1	2	3	4	5		
Group I (control–light bond)	0	0	1	9	2	12	NS
Group II (Grēngloo)	0	1	3	6	2	12	
Group III (Blūgloo)	1	2	2	6	1	12	
Group IV (Transbond Plus Color Change Adhesive)	0	1	2	5	4	12	

NS, not significant.

According to the manufacturers, Grēngloo is designed with a patented ingredient that increases traumatic impact resistance by 118 per cent. In addition, they also claim that Grēngloo's chemical affinity with metal brackets such as Damon™ 3MX and Titanium Orthos™ ensures reliable bond strength. In the present study, among the CCA, the highest bond strength was obtained with Grēngloo.

It is claimed that Transbond Plus CCA yields bond strength comparable with Transbond™ XT (http://solutions.3m.com). However, in the present study, among the CCA, the lowest bond strengths were obtained with Transbond Plus CCA. The only significant difference with the light cure adhesive was also found with Transbond Plus CCA. The differences may be due to the moisture tolerant characteristic of Transbond Plus. In moisture and saliva-contaminated environments, the real potential of the product may be expressed. Further studies are needed to clarify this issue.

Northrup *et al.* (2007) compared the SBS of Damon 2 brackets bonded with a traditional adhesive (Transbond XT) and Blūgloo. They found no significant difference in SBS, and the bond strengths were well above the required strengths for withstanding masticatory and orthodontic forces. Their results suggest that there was no compromise in bond strength when using the Blūgloo adhesive for its advantageous colour change properties or in aiding adhesive removal during bonding or debonding of brackets. Lowder *et al.* (2008) compared the bond strength of four orthodontic adhesives used with a caries-protective resin sealant. They used Blūgloo with Transbond XT as the control and the shear/peel bond strength obtained with both were similar. In agreement with those studies, the bond strengths obtained with Blūgloo and Light Bond were also not statistically different. The authors of the present study also agree with Northrup *et al.* (2007) that the main advantage of these products are colour changing properties, which make the adhesive removal process easier during bonding or debonding of brackets.

Comparison of the SBS of CCA with the traditional light cure adhesive revealed that the bonding performance of Grēngloo and Blūgloo was comparable. However, the bond strength of Transbond Plus CCA was significantly lower than that of Light Bond. The relatively higher bond strengths of Grēngloo and Blūgloo may be due to the sealant, Ortho Solo, used in these groups. Ortho Solo is a fluoride-releasing universal sealant and bond enhancer. It is composed of dimethacrylate resins, barium glass, fumed silica, sodium hexafluorosilicate, and ethanol. According to the manufacturers, Ortho Solo incorporates a bond-enhancing property that improves adhesion to the tooth at the adhesive interface, hence reducing bond failures. The glass filler, unique to Ortho Solo, acts as a stress and shock absorber, preventing cracks that can lead to bond failure. Vicente *et al.* (2005) found a significant increase in bond strength when brackets were bonded with Ortho Solo primer compared with Transbond XT primer or All-Bond 2 primer with Transbond XT adhesive. On the contrary, Northrup *et al.* (2007) did not find a significant increase in bond strength when Ortho Solo was used, albeit with the Blūgloo adhesive, compared with the other primer-adhesive combination of Transbond XT. In the present study, there was also an increase in bond strength when Ortho Solo was used with the Blūgloo and Grēngloo adhesive compared with the combination of Transbond XT Primer and Transbond Plus CCA, but the increase was not statistically significant.

The amount of adhesive remaining on the tooth was assessed using the modified ARI (Olsen *et al.*, 1997). ARI scores are used to define the site of bond failure between the enamel, the adhesive, and the bracket base. Bond failures within the adhesive or at the bracket–adhesive interface are preferred because they decrease the shear force stress at the enamel surface and increase the probability of maintaining an undamaged enamel surface (Olsen *et al.*, 1997). On the other hand, some authors consider that less adhesive on the enamel to be an advantage because less time is required to remove the remaining bond material, and the risk of damage to tooth enamel is diminished (Vicente *et al.*, 2009). In the present study, the ARI values were not significantly different between groups; most samples showed almost complete adhesion of the resin to

the bracket surface after debonding. Newman *et al.* (1995) stated that SBS should be less than 23 kg to avoid damage to enamel. In the present study, this corresponds to bond strengths of approximately 23.4 MPa. Only bond strength values obtained with Light Bond adhesive came close to this borderline value. Indeed, there were instances of enamel fracture in all of the groups tested. However, the enamel fractures observed in this study might not be directly transferable to the clinical situation because the characteristics of the masticatory and orthodontic treatment forces and those obtained with Universal testing machines are different (Lowder *et al.*, 2008).

Conclusions

1. Significant differences existed between the SBS of Transbond Plus CCA and Light Bond. Therefore, the null hypothesis was rejected.
2. Although Transbond Plus CCA yielded the lowest SBS values, no statistically significant difference was found between bond strength values of the three commercially available CCA.
3. All three CCA can be used safely in orthodontic practice since they resulted in acceptable bond strengths. In situations where extra bond strength is needed, Grēngloo and Blūgloo may be preferred.
4. A higher incidence of ARI scores 4 and 5 revealed that bond failures in all test groups were mainly adhesive in nature.

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