

Evaluation of Shear Bond Strength of Orthodontic Brackets Bonded with Nano-Filled Composites

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Abstract

Objectives: The purpose of this study was to evaluate the shear bond strength (SBS) of orthodontic brackets bonded with two types of nano-composites in comparison to a conventional orthodontic composite.

Materials and Methods: Sixty extracted human first premolars were randomly divided into 3 groups each containing 20 teeth. In group I, a conventional orthodontic composite (Transbond XT) was used to bond the brackets, while two nano-composites (Filtek TM Supreme XT and AELITE Aesthetic Enamel) were used in groups II and III respectively. The teeth were stored in distilled water at 37°C for 24 hours, thermocycled in distilled water and debonded with a universal testing machine at a crosshead speed of 1 mm/min. The adhesive remnant index (ARI) was also evaluated using a stereomicroscope.

Results: AELITE Aesthetic Enamel nano-composite revealed a SBS value of 8.44 ± 2.09 MPa, which was higher than Transbond XT (6.91 ± 2.13) and Filtek TM Supreme XT (6.04 ± 2.01). Statistical analysis revealed a significant difference between groups II and III ($P < 0.05$). No significant difference was found between groups I and III, and between groups I and II ($P > 0.05$). Evaluation of ARI showed that Transbond XT left fewer adhesive remains on teeth after debonding.

Conclusion: Results of this study indicate that the aforementioned nano-composites can be successfully used for bonding orthodontic brackets.

Key Words: Shear; Bond Strength; Nano; Composite

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INTRODUCTION

After introduction of the acid etch bonding method by Buonocore in 1955, direct bonding of orthodontic brackets was first per-

formed by Newman in 1965 [1, 2]. This method expanded so rapidly that nowadays, utilization of the acid etch technique along with light cure composites is the most common bonding

system in orthodontics [3]. Since re-bonding of brackets could be a time consuming and challenging process, achieving an appropriate bond strength is an important clinical objective [4]. While various types of composites such as microfilled, microhybrid and flowable are available, the latest development in this field has been the introduction of nano-filled composites that are claimed to achieve higher wear resistance and appropriate mechanical properties [5]. They also enhance the hybrid layer, increase marginal seal and reduce polymerization shrinkage due to their higher filler content. Furthermore, nano-filler bondings have shown satisfactory bond strength to enamel and dentin, and can be utilized for direct and indirect restorations [6, 7, 8, 9]. Therefore, it is likely that nano-filled composites may replace other types of composites in the near future [5]. Despite the extensive applications of nano-composites in restorative dentistry, there is inadequate data regarding the possibility of using them for bonding orthodontic brackets. The aim of this study was to evaluate the shear bond strength and failure sites of two types of nano-composites in comparison to the conventional orthodontic composite adhesive system, and evaluate the possibility of their clinical application in bonding orthodontic brackets.

MATERIALS AND METHODS

Sixty human first premolars were randomly divided into three groups. In order to prevent dehydration and inhibit bacterial growth, the teeth were preserved in 0.1% aqueous thymol solution immediately after extraction. Only teeth with intact buccal surfaces were selected, and any teeth with evidence of cracks, caries, hypoplastic areas or other enamel abnormalities were excluded. After thorough rinsing with water, the buccal surfaces were etched via 35% phosphoric acid gel (Ultradent, USA) for 30 seconds and then dried until a chalky appearance was visible. Standard metal premolar brackets (Dentaram, Insprington, Ger-

many) with surface area of 10.23 mm² were bonded in this study.

Three groups of brackets were bonded using the following systems: the first group was bonded using a conventional orthodontic composite: "Transbond XT (3M Unitek, USA) and Transbond XT primer". For the second group, a nano-filled bonding and composite; AdperTM Single Bond and FiltekTM Supreme XT (3M ESPE, USA) was used. In the third group, bonding was performed via another nano-filled composite bonding system; AeliteTM Aesthetic Enamel (Bisco, USA) and One-Step Plus.

The bonding process was initiated by placing a thin layer of bonding on the enamel surface and light curing for 10 seconds. After that, the main bulk of composite was placed onto the bracket bases and pressed with a force of 300 G using a force gauge. 300 gram force was applied by means of a force gauge.

The excess composite was subsequently removed using a sharp scaler.

After that, the samples were light cured for 40 seconds (10 seconds on each side) using a standard halogen light-curing unit (Optilux, 3M Unitek). The samples were then placed in 37°C distilled water for 24 hours, followed by thermocycling for 2000 times at temperatures between 5°C and 55°C. A mounting jig was used to facilitate mounting each tooth onto an acrylic block.

In order to prevent deformation of brackets during the debonding process, a stainless steel wire (0.018×0.025 mm) was inserted into the brackets' slots during mounting. After completion of acrylic setting, the samples were placed in a universal testing machine (Zwick GmbH 8 Co, Germany) in a manner that the labial surfaces of the teeth were parallel to the shearing force. A wire loop was connected to the machine and an occlusing force with a crosshead speed of 1mm/min was exerted onto each sample. The SBS value for each sample was determined by dividing the maximum force by the surface area of the brackets.

In order to investigate the sites of bond failure, Adhesive Remnant Index (ARI) was determined for each sample by observation of the tooth surface under a stereomicroscope at $\times 10$ magnification and based on the following scale:

0: No adhesive is remained on the tooth surface

1: Less than 50% of the adhesive is remained on the tooth surface

2: More than 50% of the adhesive is remained on the tooth surface

3: 100% of adhesive is remained on the tooth surface

Mean and standard deviation (SD) values for SBS in each group were determined. One way Analysis of Variance and Tukey HSD multiple comparisons was used for statistical analysis of SBS. Statistical significance was set at $p \leq 0.05$. Statistical analysis of ARI was performed using Kruskal-Wallis test.

RESULTS

Descriptive values of the shear bond strength for the three groups are shown in Table 1. The results of this study revealed that AELITE Aesthetic Enamel had the highest SBS value (8.44 ± 2.1), whilst Transbond XT (6.92 ± 2.13) and Filtek TM Supreme XT (6.05 ± 2.02) were in the next ranks.

One-way ANOVA test showed statistically significant differences between the shear bond strengths of the three groups ($p = 0.019$).

Multiple comparisons revealed that the shear bond strength of AELITE Aesthetic Enamel was significantly higher than the other two groups ($p < 0.001$), whilst there was not a statistically significant difference between Transbond XT and Filtek TM Supreme XT ($p = 0.453$).

Furthermore, Table 2 illustrates the Adhesive Remnant Indices. There was not any statistically significant difference between ARI Indices of the three groups ($p = 0.142$).

DISCUSSION

The results of the present study revealed that AELITE Aesthetic Enamel nano-composite showed the highest SBS value, followed by Transbond XT and Filtek Supreme XT respectively; however, these differences were not statistically significant ($P > 0.05$).

Therefore, it can be concluded that there is no significant difference in the shear bond strengths of Transbond XT and the nano-composites.

According to a study by Reynolds et al., an appropriate adhesive for orthodontic purposes should meet a SBS value of at least 5.9-7.8 MPa [10].

Therefore, in addition to Transbond XT, both Supreme XT and AELITE Aesthetic Enamel are appropriate for orthodontic purposes and could be utilized for bonding, despite not displaying any additional advantages compared to Transbond XT [10].

Table 1. Shear Bond Strength values in the tested groups.

| Composite Name | n | Mean | Std. Deviation | 95% confidence interval | Min. | Max. |
|---------------------------------|----|------|----------------|-------------------------|------|-------|
| Transbond XT | 20 | 6.92 | 2.13 | 5.92-7.92 | 3.62 | 11.8 |
| Filtek TM Supreme XT | 20 | 6.05 | 2.02 | 5.10-6.99 | 2.09 | 9.46 |
| AELITE Aesthetic Enamel | 20 | 8.44 | 2.10 | 7.46-9.43 | 3.17 | 11.88 |

Since various studies regarding bond strength of composites have utilized adhesives with different size/concentration of filler, it is difficult to compare their results accurately [11]. This is further complicated by different medians and thermocycling rounds [12]. The results of this study are consistent with that of Bishara et al. [13], whereby there was no significant difference between the SBS value of Transbond XT and a restorative nano-composite, and both materials were considered applicable in orthodontics. On the other hand, our results were inconsistent with that of Uysal et al., whereby comparison of SBS of a nano-composite (Filtek Supreme Plus Universal) and a nano-ionomer (Ketac™ N100 Light Curing Nano-Ionomer) with Transbond XT revealed a significantly higher SBS value of Transbond XT [14].

However, such different findings may be due to a number of factors; in the study by Uysal et al., the teeth were polished with nano-fluoridated pumice, which may have interfered with the entrance of nano-fillers into the etched enamel surface, and led to decreased bond strength.

A further significant difference in addition to the use of a QTH light source was their use of porcelain based brackets compared to the use of metal brackets in our study.

In addition, in the study by Uysal et al., the penetrance of the bonding agent in all of the groups was not matched, as Transbond XT paste was applied onto uncured bonding while in the case of the nano-composites; the bonding was cured prior to application of the paste. For purpose of testing orthodontic shear bond strength, a previous study has shown that the wire loop method has been found to be superior to the shear blade method that was used in the study by Uysal et al. [15].

The results of the present study revealed that in the majority of samples of Transbond XT and Supreme XT, bond failure occurred in a manner that less than 50% of the original composite had remained on the enamel surfaces (Grade 1). Meanwhile, in AELITE Aesthetic Enamel group (displaying highest SBS value), more than 50% of the original composite had remained on the enamel surfaces (Grade 2). Unfortunately, the Adhesive Remnant Index has not been reported in Bishara's study. However, Uysal et al. revealed that the ARI was Grade 1 in all of the groups, which is consistent with our results for Transbond XT and Supreme XT. On the other hand, in our study, the majority of the samples in AELITE Aesthetic group were in Grade 2, which was the second rank amongst the composites in our study.

Table 2. Frequency of distribution of adhesive remnant index (ARI) scores (%) in different groups.

| Composite | | Adhesive Remnant Index (ARI) | | | | Total |
|----------------|---|------------------------------|------|------|----|-------|
| | | 0 | 1 | 2 | 3 | |
| Transbond XT | n | 0 | 20 | 0 | 0 | 20 |
| | % | 0 | 100 | 0 | 0 | 100 |
| Filtek Supreme | n | 0 | 12 | 5 | 3 | 20 |
| | % | 0 | 60 | 25 | 15 | 100 |
| Bisco Aelite | n | 0 | 5 | 15 | 0 | 20 |
| | % | 0 | 25 | 75 | 0 | 100 |
| Total | n | 0 | 37 | 20 | 3 | 60 |
| | % | 0 | 61.7 | 33.3 | 5 | 100 |

CONCLUSION

Overall, it can be concluded that the failure sites of Transbond XT and nano-composites is mainly at the tooth-adhesive interface. Considering the results of this study and Bishara's study, successful application of nano-composites can be recommended for bonding orthodontic brackets.

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