Evaluation of the adhesive efficiency of pre-heated composite for bonding orthodontic brackets

Ghada A. Salem[1], Wael Mohamed Gamal[2], Omnia A. Elhiny[3]

[1]Associate Professor of Pedodontics, Orthodontics and Pediatric Dentistry Department, National Research Centre. Affiliated to Nahda University.
[2]Lecturer, Operative Dentistry Department, Faculty of Dentistry, MTI University.
[3]Omnia A. Elhiny, Associate Professor of Orthodontics, Orthodontics and Pediatric Dentistry Department, National Research Centre.
Email: omniaelhiny@yahoo.com

Abstract
Aim: The aim of this study was to investigate the adhesive efficiency of preheated nanohybrid composite in bonding orthodontic brackets compared to Transbond XT and flowable composite. Material and Methods: Forty-five orthodontically extracted premolars were randomly divided into 3 groups. For group I, Transbond XT was the adhesive of choice, for group II; flowable composite, while for group III preheated nanohybrid composite was used. All the samples were exposed to thermocycling for 1000 cycles and then the shear bond strength and the adhesive remnant index (ARI) were determined for each group. Results: There was a statistically significant difference between group 1 and the other two groups (p<0.001). There was no statistically significant difference between group 2 and group 3 (p=0.896). ARI scores 2 and 3 showed the highest frequency in all groups. Conclusion: Despite having a clinically acceptable bond strength, the short manipulation time of the preheated nanohybrid composite presented a limitation for its use and might have affected its bond strength. Transbond XT showed the highest bond strength while flowable composite displayed the lowest bond strength.

Keywords: Flowable composite, preheated nanohybrid composite, Transbond XT, shear bond strength.

INTRODUCTION

Acid etched composite has been widely used for the bonding of orthodontic brackets. However, it has a number of drawbacks including the increased possibility of enamel loss after acid etching or during debonding,[1,2] the decreased bond strength in the presence of saliva, and incomplete polymerization with the formation of residual monomer.[3] In addition, the bonding procedure is prolonged as it involves a number of steps such as enamel conditioning, applying the bonding agent and finally the adhesive resin.[4,5]

Flowable composites have been used by many orthodontists in bonding orthodontic brackets. They have a lower viscosity compared to conventional composites; as they have a low filler content.[6] As flowable composite can penetrate adequately into the retentive areas of the bracket base and into the etched enamel, it can increase the retention of the bracket and also increase the ability of the adhesive to resist bracket drift during bonding.[7-9] However, despite having an acceptable bond strength; Ryou et al[10] and Tecco et al[11] found that flowable composite had a lower bond strength than the conventionally used Transbond XT composite.

Preheated composite was first introduced by Friedman in 2001.[12] It was reported that raising the temperature of the composite with a high filler content might enhance its physical and mechanical properties; through improving its flowability, increasing its adaptability and shortening the curing time which increases its durability.[12-16]

Many researchers have tested the accuracy of the preheated composite as a restorative material and found that it had a lower viscosity and an improved hardness.[17] Nevertheless, there were no studies, to our knowledge, on its efficiency as an adhesive bonding system for orthodontic brackets. Hence, the purpose of this study was to investigate the adhesive efficiency of preheated nanohybrid composite in bonding orthodontic brackets compared to Transbond XT and flowable composite.

MATERIAL AND METHODS

In this in vitro study, forty-five orthodontically extracted premolars were collected and stored in a 0.1% thymol solution at 4°C until they were used. The teeth were used within 6 months following their extraction. Any tooth with a crack, caries or restoration was excluded from the study. The sample was divided equally and randomly into three groups using a computer - generated randomization list (Random sequence generator; www.random.org). Each group comprised of 15 teeth.

The buccal enamel surface of each tooth was cleaned using pumice and washed with distilled water, then it was etched with 37% phosphoric acid gel (Etch-37, Bisco, Schaumburg, Ill) for 30 seconds, rinsed and air dried for 20 seconds. A single layer of the adhesive primer (XT, 3M, Unitek, Monrovia California USA) was applied uniformly on the etched enamel surface using a dental micro brush and light cured for 10 sec. Then, the composite was applied to the base of the bracket (Roth Rx, 3M Gemini 0.022” slot, metal brackets). The bracket was placed on the middle third of the labial surface of each tooth using hand pressure, then a 300gm load was applied for 30s for standardization. The excess composite was removed from around the bracket using a hand scaler and the bracket was light cured (halogen lamp – light curing device, 3M Unitek, Monrovia, CA) for 40 seconds; 10 seconds for each side.

The groups were classified such that for **Group I**: Transbond XT bonding system (3M Unitek, Monrovia, Calif.) was the composite of choice. In **Group II**: flowable composite (GF, Grandio Flow, VOCO, Cuxhaven, Germany) was used, while in **Group III**: preheated nanohybrid composite (Grandio, VOCO, Germany) was utilized after preheating in the heating unit (VisCalor dispenser, Calset TM AdDent, Inc. Danbury, CT USA) for 30seconds to a temperature of 54^{0}C-60^{0}C.

After bonding the brackets in all groups, the teeth were stored in a well-sealed container filled with distilled water at 37^{0}C for 24 hours to allow for adequate water absorption.

Thermocycling procedures:
For the simulation of oral conditions, all the samples were subjected to thermocycling for 1000 cycles in 24 hours (100 SD Mechatronic thermocycler, Germany). The samples in each round were immersed in a 5^{o}C water bath for 15 seconds; with a transfer time between baths of 10 seconds and then they were immersed in a 55°C water bath for another 15seconds; as recommended by the International Organization for Standardization.[18]

Shear bond strength test (SBS):
The teeth were inserted in standardized acrylic blocks (20x24mm), till the cementoenamel junction. The labial surface of each tooth was aligned perpendicular to the bottom of the block; thus, parallel to the applied force during the SBS test. Each tooth was designated a two-digit number such that the investigator was blinded to the sample group.

A 0.02 inch" stainless steel wire loop was ligated under the lower wings of the bracket and attached to the cross head of the machine. Shearing force was applied occlusso-gingivally through a 0.6 mm thick edge chisel-shaped blade, with a cross-head speed of 0.5 mm/min until the bracket debonded. The maximum loading force was recorded in Newtons and the readings were divided by the bracket base surface area to determine the SBS in mega Pascals (MPa).

Failure mode assessment:
After debonding the brackets, the enamel surface was examined under a stereomicroscope (MA 100 Nikon stereomicroscope Japan) with 50X magnification; in order to determine the adhesive remnant index (ARI), modes of bond failure, and the residual adhesive quantity on each tooth.

The modified Adhesive Remnant Index (ARI) [2, 24] was evaluated according to the following scale:

Score 1 = all of the bonding resin with an impression of the bracket base seen on it remained on the tooth surface. Score 2 = more than 90 per cent of the bonding resin remained on the tooth surface. Score 3 = more than 10 per cent but less than 90 per cent of the bonding resin remained on the tooth. Score 4 = less than 10 per cent of the bonding resin remained on the tooth; and Score 5 = no bonding resin remained on the tooth.

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, shear bond strength data showed parametric (normal) distribution, while ARI score data showed non-parametric (not-normal) distribution. For parametric data: One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related samples. For non-parametric data: Kruskal Wallis test was used to compare between more than two groups in non-related samples. Mann Whitney test was used to compare between two groups in non-related samples.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Shear bond strength:
The means and standard deviations are shown in **Table 1** and **Figure 1**.

There was a statistically significant difference between (Group 1), (Group 2) and (Group 3) where (p<0.001).

A statistically significant difference was found between (Group 1) and each of (Group 2) and (Group 3) where (p<0.001).

No statistically significant difference was found between (Group 2) and (Group 3) where (p=0.896).

Table 1: The mean, standard deviation (SD) values of shear bond strength of different groups

Variables	Shear bond strength	
	Mean	SD
Group 1 (Transbond XT)	7.47	1.11
Group 2 (preheated nanohybrid)	5.35	1.28
Group 3 (flowable)	5.18	0.52
p-value	**<0.001***	

*; significant (p<0.05)

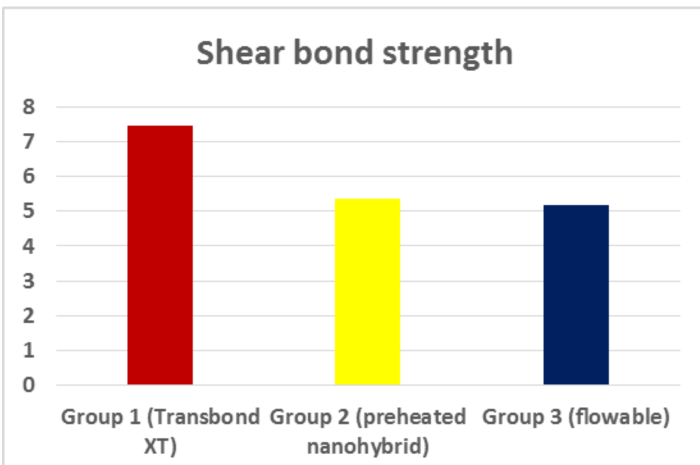


Figure 1: Bar chart representing shear bond strength for different groups

ARI score:
The means and standard deviations of the ARI score in different groups is shown in **Table 2**, while the frequency values are shown in **Table 3** and **Figure 2**. **Figure 3**, shows Stereomicroscopic scans of the most frequent scores encountered in all groups.

There was no statistically significant difference between (Group 1), (Group 2) and (Group 3) where (p=0.111).

Table 2: The mean, standard deviation (SD) values of ARI score of different groups

Variables	ARI score	
	Mean	SD
Group 1 (Transbond XT)	2.67	0.49
Group 2 (preheated nanohybrid)	2.67	0.49
Group 3 (flowable)	2.33	0.49
p-value	**0.111ns**	

ns; non-significant (p>0.05)

Table 3: The frequencies values of ARI score of different groups

Variables		ARI score	
		n	%
Group 1 (Transbond XT)	**Score 2**	5	33.3%
	Score 3	10	66.7%
Group 2 (preheated nanohybbrid)	**Score 2**	5	33.3%
	Score 3	10	66.7%
Group 3 (flowable)	**Score 2**	10	66.7%
	Score 3	5	33.3%
p-value		**0.111ns**	

ns; non-significant (p>0.05)

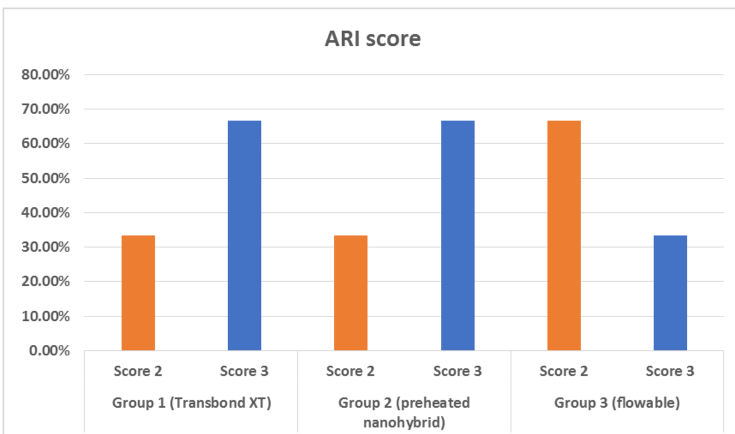
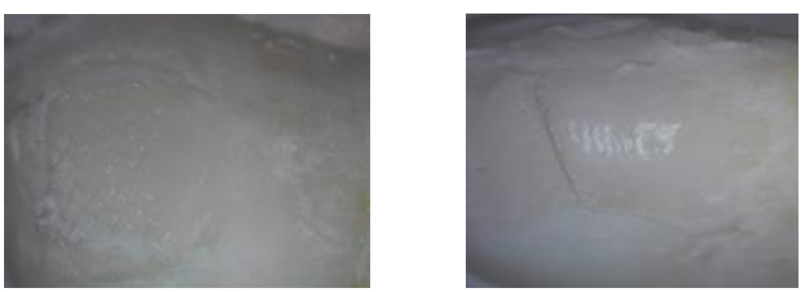


Figure 2: Bar chart representing ARI score for different groups



A B

Figure 3: Stereomicroscopic photos representing the most frequent types of failure:
a: Score 2 b: Score 3

DISCUSSION

The main goal of orthodontic adhesion is to provide an adequate bond strength for orthodontic brackets, in order to withstand the masticatory and orthodontic forces. The shear bond strength relies on several variables; such as the adhesive quality of the bonding material, the type and quality of polymerization of the bonding agent and the adhesion at the tooth-composite and the composite-bracket interfaces.[19,20]

There are several generations of composite adhesives that have been developed to provide increased bond strength. Micro hybrid universal and Nanohybrid composite resins have superior mechanical properties, but due to their high viscosity; the possibility of forming internal voids may increase.[21] Preheating the composite may increase its flowability and thus decrease the internal voids. It also can improve the mechanical and physical properties and increase the bond strength.[21,22] In this study, nanohybrid composite resin was warmed using VisCalor dispenser; which is the new rising generation instead of the conventional caps warmer and caps dispenser.

Using this system, the quick execution of the whole procedure is crucial to minimize the drop of temperature that might occur before bonding, as much as possible, and therefore achieve the best clinical performance. For this reason, the heating procedures were done very close to the prepared specimen to allow for the quick application and minimum amount of heat loss during bonding.

Thermocycling is considered as a method for evaluating the effect of stresses on the strength of the tooth-bracket interface.[23] It lowers the shear bond strength (SBS) compared to the samples that were not thermocycled.[24,25] These stresses occur inside the composite as a result of being exposed to different temperatures that either create weak areas inside the adhesive, or result in the absorption of more water causing hydroscopic expansion and degradation of the material.[26-28] In this study, thermocycling was done for all the specimens to simulate the oral conditions, while many studies evaluated the SBS after storing their specimens in water for 24 hours; which hardly fit the oral situation to which the brackets are usually exposed to.[25,26]

The Transbond XT adhesive, which is the most commonly used adhesive for bonding orthodontic brackets; showed the highest mean SBS (7.47±1.11MPa), that was similar to the mean reported by Shapinko Y et al.[29] On the other hand, it was lower than that observed in other studies,[30-32] which may be due to the different types of brackets used, and the fact that thermocycling decreased the bond strength of the adhesive. The SBS of the Transbond XT was significantly higher than the preheated nanohybrid composite. This could be explained by the quick drop of the composite temperature during application which is influenced by the room temperature and might have affected the bond strength. Moreover, this rapid drop in temperature resulted in rapid hardening of the material during application; presenting a difficulty in manipulation and bonding. Many studies reported the application time of preheated composite resin to be within 8 to 10 seconds which is a very short time for the bonding of orthodontic brackets.[17,22,33] However, the observed bond strength of the preheated nanohybrid composite was 5.35 MPa which could be considered clinically acceptable as the previously reported SBS that was considered acceptable for routine clinical use was between 2.8 to 10 MPa.[34-37] This shows that it had an adequate flow into the enamel porosities as well as the potential to provide a more comparable bond strength if it was modified to provide more application time and the temperature drop was controlled.

In addition, despite that the mean bond strength of flowable composite was within the clinically acceptable range (5.18±0.52 MPa),[10,29] the Transbond XT bond strength was significantly higher; which agreed with the findings of Ryou et al[10] and Tecco et al.[11] Those results could be explained by looking at previous researches reporting that flowable composite had inferior mechanical properties compared to conventional adhesives due to its low filler content.[30,38] This reduction in filler content resulted in a decrease in the contact area between the filler and the resin matrix which in turn reduced the bond strength.[37] On the other hand, there was no significant difference between the flowable composite group and the preheated nanohybrid composite group as they both had mean bond strength within the same clinically acceptable range with the flowable composite having an even lower mean shear bond strength than the preheated nanohybrid composite. Both had lower SBS than Transbond XT. To our knowledge, the preheated nanohybrid composite has never been used for bonding orthodontic brackets before, which presented a limitation for comparing the results.

Preservation of an intact enamel surface without damage is the main goal after debonding. An ARI score of 0 or 1 always denotes enamel fracture at the enamel-adhesive interface, while an ARI score 2 or 3 means that the bond failure is at the bracket-adhesive interface, thus keeping the enamel surface intact.[30,39] The results showed that there was no significant difference between the three groups in the ARI scores. In all groups, scores 2 and 3 were the most frequently observed; with the occurrence of bond failure mostly at the adhesive-bracket interface similar to previous studies.[2,30,31] It is obvious that if the failure occurred at the tooth-adhesive interface, it is more likely that enamel stripping will occur during debonding. Hence, D'Attilio et al[30] stated that when the bonding composite does not release fluoride it is more desirable that the failure happens at the bracket-adhesive interface.

Within the limitations of this study, it could be deducted that Transbond XT had adhesive characteristics superior to the other composite materials. Even though the bond strength of the preheated nanohybrid composite was clinically acceptable, its applicability in orthodontics is questionable due to the rapid drop in temperature that occurred during application and which resulted in hardening of the material presenting a difficulty in manipulation and bonding.

CONCLUSION

- The preheated nanohybrid composite despite having a clinically acceptable bond strength, its use as an orthodontic adhesive is not advisable due to the short manipulation time it provides before the temperature drops.
- Transbond XT showed a higher bond strength in bonding orthodontic brackets compared to both the preheated nanohybrid and flowable composite.
- Flowable composite had a lower bond strength compared to both the Transbond XT and the preheated nanohybrid composite.

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