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Effect of pre-heated resin composite application on the shear bond strength of orthodontic brackets after thermal aging

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Abstract
To evaluate the effects of pre-heated resin composite application on the shear bond strength (SBS) of orthodontic metal brackets. A total of 80 human premolar teeth randomly divided according to the composite type (microhybrid, nanohybrid, nanofilled and conventional) and temperature (25 °C-60 °C). Teeth were bonded with same light-cured adhesive and different composite types (n=15). Thermal cycling was then used for ageing procedure on all samples. After storage in distilled water for 24 h, the brackets were subjected to SBS test at a speed of 0.5 mm/min until bracket debonding. SBS values and the Adhesive Remnant Index (ARI) were evaluated. Data were analyzed using the one-way ANOVA and the Tukey post-hoc test ($p<0.05$). A statistically significant difference was found between test groups at 25 °C. Teeth bonded with preheated composites showed a statistically higher SBS than those bonded with lower temperature composites. Pre-heated nanofilled and conventional orthodontic composite showed the highest SBS among all the pre-heated groups. Pre-heating of nanofilled composites may be play an important role for improvement of the orthodontic bracket SBS.

Keywords: Orthodontic, composite heating, shear bond strength

1. Introduction

The success of the orthodontic treatment, among other factors, is greatly influence by accurate bracket positioning and long-term retention of these accessories. Failures during bracket bonding can disrupt and delay the treatment, increase the cost, and hinder a correct finalization of the case. Frequent bracket re-bonding can also cause damages to the enamel structure [1]. To enable a controlled three-dimensional orthodontic tooth movement, good bond strength between bracket, adhesive and tooth enamel is required. Bond strength should be strong enough to withstand the oral environment conditions, the forces of mastication and the strains generated by treatment mechanics. However, it should not be excessively strong to the point of making bracket removal difficult or damaging the enamel surface [2]. Since Buonocore introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel has developed applications in all fields of restorative dentistry, including orthodontic brackets bonding [3].

The composition of orthodontic composite resins is very similar to that of those used in restorative dentistry. They consist of an organic matrix (Bis-GMA, TEGMA), initiators and an inorganic filler content, which occupy approximately 77% of their total weight. The filler content is responsible for the increase of the mechanical properties of the material, such as strength and wear resistance. The fact that their composition is similar to that of the composite resins used in restorative dentistry has led to the indication of low-viscosity flowable composites for bracket bonding instead of orthodontic composite [4-6]. To broaden the options for orthodontists, the possibility of using traditional composite restoratives has been raised to bond orthodontic brackets. The shear bond strength (SBS) test has been used to evaluate the suitability of bonding brackets with composite restoratives. Although similar results between composite restoratives and traditional orthodontic adhesives have been achieved [7-9], other authors have reported lower SBS mean values for composite restoratives [10]. In fact, the higher viscosity observed with composite restoratives tends to compromise their ability to adhere to the bracket base. Thus, if composite restoratives were made more flowable to readily adhere to the bracket base, they could be potentially used to bond orthodontic brackets.

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Recently, preheating resin composites have been advocated as a method to increase composite flow, improve marginal adaptation and monomer conversion [11-12]. Dental composites have typically been classified according to their filler characteristics, particularly the particle size. Currently, three categories have been proposed for resin composite filler particles: microfilled composites, microhybrid composites, and nano composites (nanofilled or nanohybrid resin composites) [13, 14]. However, there has been a lack of studies evaluating the influence of preheating traditional composite restoratives on the SBS of orthodontic brackets. One study was reported that the use of pre-heated composite restoratives and orthodontic adhesives might be an alternative approach to bond orthodontic brackets [15]. This study aimed to evaluate the SBS of orthodontic brackets when bonded with either pre-heated or at room temperature composite restoratives in comparison to a conventional orthodontic adhesive.

2. Materials and methods

Following appropriate patients consent, 80 human premolar teeth were collected and stored in 0.5% Chloramine T solution at 4 °C and used within 3 months after extraction. A total sample size of 80 teeth (10 teeth per group) would give more than 70% power to detect significant differences with a 0.20 effect size between eight groups and at a p=0.05 significance level. Teeth with hypoplastic enamel, cracks, fractures, caries, restoration or pretreatment with a chemical agent such as alcohol, formalin, or hydrogen peroxide were excluded. Teeth were cleaned, and calculus soft tissue remnants were removed. All teeth were mounted vertically in chemically activated acrylic resin until two-thirds of the root was embedded. Teeth polished with a non-fluoridated pumice and rubber prophylactic cup. The teeth were then rinsed in a stream of water for 10 s and dried. Teeth were divided into eight equal groups.

The following materials were tested: a microhybrid composite restorative (Filtek Z250, 3M ESPE, St. Paul, MN), nanohybrid composite restorative (Filtek Z550, 3M ESPE) a nanofilled composite restoratives (Filtek Ultimate, 3M ESPE), and a conventional orthodontic fixation system (Transbond XT, 3M Unitek, Monrovia, CA). One syringe containing the orthodontic adhesive and another three tubes, each containing a different composite restorative material, were stored in the oven (incubator) at 25 °C. At the same time, another syringe containing the same orthodontic adhesive and other four syringes, each containing a different composite restorative material, were stored at 60 °C. All composites comprising the same material belonged to the same batch and were kept in the oven (incubator) for 1 h before starting the adhesive procedure [15].

A conventional etch-and-rinse system and a light-cure primer (Transbond XT primer, 3M Unitek, Monrovia, CA, USA) were used for bonding procedures. The enamel surfaces were etched for 15 s with 37% phosphoric acid (Gel Etch, 3M Unitek, Monrovia, CA, USA), rinsed with water for 15 s, and air dried for 15 s. A thin coat of Transbond XT primer was applied to the enamel surfaces and light cured for 15 s. The light-cured orthodontic composite (Transbond™ XT, 3M Unitek, Monrovia, California, USA) and other restorative composites was used to bond the brackets to the teeth. One hundred twenty metal brackets (0.018-inch slot; Roth–Equilibrium®, Dentaurum, Pforzheim, Germany) were bonded to all teeth by a single operator. After the bracket-bonding procedure, all bonded teeth were stored in distilled water at 37 °C for 1 day. To simulate the oral environment, all samples were then thermo cycled for 5000 cycles between 5 and 55 °C with a dwell time of 15 s in each water tank (Thermocycler, Willytec, Munich, Germany).

Shear bond strengths were measured on a universal testing machine (TSTM 02500, Elista Ltd, Şti, Istanbul, Turkey), at a crosshead speed of 0.5 mm/min. The results were recorded in newtons and converted to megapascals (MPa=N/mm2). Debonding surfaces were examined under a stereomicroscope (SZ-40 Olympus, Japan) at 40X magnification. The adhesive remnant index (ARI) system was used to classify failure types [15]. All statistical analyses were conducted with the Statistical Package for Social Sciences (SPSS 21.0 for Windows, SPSS Inc., Chicago, IL, USA). Statistical significance was set at a probability value of $p<0.05$. Since, the results of Kolmogorov-Smirnov and Shapiro-Wilk tests showed that the data were normally distributed ($p>0.05$), parametric tests were used for statistical analysis. Descriptive statistics including the mean, standard deviation, minimum, and maximum values were calculated for groups. The data were analyzed with twoway analyses of variance (ANOVA), and a post hoc Tukey's test.

3. Results & Discussion

Mean shear bond strength values of the groups are listed in Table 1. ANOVA analysis showed significant differences among the eight groups ($p<0.01$). A statistically significant difference was found between test groups at 25 °C. Teeth bonded with preheated composites showed a statistically higher SBS than those bonded with lower temperature composites. Pre-heated nanofilled and conventional orthodontic composite showed the highest SBS among all the pre-heated groups. Conversely, the pre-heated microhybrid composite restorative showed the lowest SBS mean. All pre-heated composite restoratives tested in the current project presented a higher SBS mean than Transbond XT stored at 25 °C, except for microhybrid composite group. The ARI scores for the groups tested are listed in Table 2. The G-test indicated that there were not significant differences among the eight groups ($p>0.05$).

This study showed that all preheated composite materials tested showed enhanced shear bond strength. Some studies had already pointed to a direct relation between pre-heating and the degree of conversion of composites. The polymerization reaction is related to the temperature and higher temperatures increase the degree of conversion, which may improve the physical properties of composite resins. Studies indicate that higher degree of conversion is due to raised temperature compared to room temperature photo polymerization and at this temperature the composite resin needs less time to set. The raising temperature enhanced flow in consequence of thermal energy that increases the molecular mobility of monomer chains and increases the collision frequency in the composite resin [16]. Daronch and Rueggeberg also reported that higher molecular mobility and reduced viscosity due to increased temperature are correlated with the decrease in film thickness of composite resin [17]. Therefore, it is likely that all resin-based materials tested in the present study had an increased degree of conversion after being pre-heated at 60 °C. Moreover, the lower viscosity of pre-heated materials might have favored a higher flow of the material into the base mesh, creating a stronger interaction between the bracket and the composite materials. The decreased viscosity of pre-heated composite restoratives is likely to render them suitable for bonding orthodontic brackets.

The conventional orthodontic adhesive tested (Transbond XT) showed the highest SBS mean value of all the materials pre-heated at 60 °C. Borges *et al* reported same results, they found the highest SBS value in conventional group, but they did not used thermo cycled their specimens. Transbond XT contains diphenyliodonium hexafluorophosphate, a ternary onium derivate system that has been shown to improve the polymerization rate of experimental resins, leading to a higher degree of convertion. The increased prepolymerization temperature contributed to improve the polymerization provided by the ternary onion derivate system, which probably fostered a higher mechanical strength network to preheated Transbond XT [18].

In the current study, which subjected samples to thermal aging, was designed to simulate clinical situations while trying to avoid some of the usual hurdles of clinical studies. Thermal cycling simulates the introduction of hot and cold extremes in the oral cavity and shows the relationship of the linear coefficient of thermal expansion between tooth and bracket bonding. The use of intermediary baths and different temperatures has been described but the use of ISO standardization (5°-55 °C) allows for a better comparison between studies. Currently, there is no universally accepted minimum clinical bond strength. However, bond strengths of 6 to 10 MPa are suggested as sufficient for most clinical orthodontic bonding requirements. One study suggested that minimum bond strength of 6 to 8 MPa was adequate for most clinical orthodontic needs [19]. These bond strengths are considered able to withstand masticatory and orthodontic forces. In this study, all bond strength values obtained were much above this minimal requirement.

3.1 Tables

Table 1: Descriptive statistics of shear bond strengths in MPa and comparison of the groups.

Groups		Mean	S.D.	Min-Max	ANOVA	Tukey
25 °C	Microhybrid Z250	6.3	0.6	4-7.2	p<0.001	A
	Nanohybrid Z550	7.2	1.7	3-9.1		A
	Nanofilled Filtek Ultimate	7.0	1.9	4-10.3		A
	Conventional Transbond XT	9.0	1.4	7-13.2		B
60 °C	Microhybrid Z250	7.5	1.2	5-10.0	F=32.723	C
	Nanohybrid Z550	8.0	1.3	3-10.1		C
	Nanofilled Filtek Ultimate	9.3	1.3	3-12.0		D
	Conventional Transbond XT	9.8	1.2	6-13.2		D

Means with the same capital letter are not statistically different from each other (p>0.05).

Table 2: Frequency of distributions and comparison of ARI scores (%).

	1	2	3	4	5
Microhybrid Z250 25 °C	90	10	-	-	-
Nanohybrid Z550 25 °C	80	20	-	-	-
Nanofilled Filtek Ultimate 25 °C	70	20	-	-	-
Conventional Transbond XT 25 °C	50	10	30	10	-
Microhybrid Z250 60 °C	70	10	20	-	-
Nanofilled Filtek Ultimate 60 °C	60	20	10	10	-
Conventional Transbond XT 60 °C	40	20	30	10	-

ARI scores, 1: all of adhesive, with impression of bracket base, remained on enamel; 2: more than 90% of adhesive remained; 3: more than 10% but less than 90% of adhesive remained; 4: less than 10% of adhesive remained ; 5: no adhesive remained on enamel. (p≥0.05)

4. Conclusions

Teeth bonded with preheated composites showed a statistically higher SBS than those bonded with lower temperature composites. Pre-heated nanofilled and conventional orthodontic composite showed the highest SBS among all the pre-heated groups. Pre-heating of nanofilled composites may be play an important role for improvement of the orthodontic bracket SBS.

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