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Comparison of Viscosity among Four Orthodontic Adhesive Primers in Two Different Temperatures

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Abstract

Statement of Problem**:** The viscosity of orthodontics adhesive primers is crucial for stability and correct brackets ‘position during bond up. An excessive adhesive flow during brackets seating could change the brackets’ position.

Objectives**:** The main purpose of this study was to investigate the viscosity of four orthodontic adhesive primers in two different temperatures.

Materials and Methods: Four orthodontic adhesive primers were used in this study. They include Transbond self-etching primer (SEP; 3M Unitek, USA), Transbond XT (3M Unitek, USA), Transbond moisture insensitive primer (MIP; 3M Unitek, USA), and Unite adhesive primer (3M Unitek, USA). A controlled stress rheometer (Carri-Med MKII, UK) with truncated cone and plate were used to investigate the viscosity of each orthodontic adhesive primer in two different temperatures. The orthodontic adhesive primers were tested at 25°C and 35°C for five times to calculate the means for each material during ascent and descent of the controlled stress rheometer. Statistical analysis was done with one-way ANOVA and two-sample t-test.

Results**:** In this study, a statistically significant difference was found among viscosity of different orthodontic adhesive primers ($p = 0.005$). At 25°C, the Transbond XT (192.20 ± 1.21 MPa·s) was the most viscous primer and Transbond MIP (21.74 ± 1.50 MPa·s) the least viscous one. Unite adhesive primer (143.40 ± 2.17 MPa·s) was the second most viscous primer followed by Transbond SEP (44.28 ± 3.09 MPa·s). The difference of the viscosity of orthodontic adhesive primers was also statistically significant when compared in two different temperatures.

Conclusions: This study showed that there was a statistically significant difference among the viscosity of the four orthodontic adhesive primers. Moreover, the viscosity of orthodontic adhesive primers also changed with temperatures. This might affect the orthodontic bond up procedure during summer and winter.

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Introduction

Commercially available orthodontic resins have different viscosities and filler particle concentrations [1]. It is used along with orthodontic adhesive primer to bond brackets to the enamel surface. Orthodontic primer is different from composite resin in the absence of filler particles. The use of primers is crucial in bonding procedure primarily due to their viscosity and superior diffusion into the enamel rods [2]. Different viscosity and consistency of each primer will give different characteristics in bonding of orthodontic brackets.

Orthodontic adhesive primer could improve the interfacial adaptation and bond strength between the enamel and composite resin. A low viscosity primer will allow better flow into the enamel surface to create deeper resin tags. The microscopic mechanical interlock of the resin tags is the primary element that gives rise to the bond between the enamel and resin. The more contact between the adhesive and surface, the greater the number of interlocks; and hence greater bond strength [3]. A low viscosity orthodontic adhesive primer will spread easily on the enamel surface and thus result in an increased contact area.

In addition, to ensure the correct bracket position, the flow of adhesive primer during bracket seating must be even. Uneven adhesive under orthodontic bracket can lead to rotation of the bracket position [4]. Excessive adhesive flow during bracket seating could change a correct bracket position. An ideal bracket base that fits well on the tooth surface must have an even flow of adhesive material during seating [5]. This is why many efforts have been made to improve adhesive resin by development of a new primer (monomer) and resin (filler).

The viscosity of orthodontic primer and penetration of the resin into the bracket base interface could influence orthodontic attachment to the enamel surface. The strength and physical properties of the resin tags are determined by the degree of penetration [6]. The greater the ability to flow, the higher the degree of penetration and the higher the bonding strength. Low viscosity cement could, therefore, penetrate into pores effectively compared to high viscosity cements [6].

However, adhesive resin materials with very low viscosity and high flow rate are not ideal for bracket bonding. Uysal *et al.* in 2004 compared the shear bond strength of different flowable composites with conventional orthodontic adhesive [7]. They found that flowable composite was not suitable for bracket bonding due to the high bond failure rate. The flowable composite did not bond effectively to the bracket as the conventional orthodontic adhesive because of its low shear bond strength [7].

An alternative method of bonding is the use of acidic orthodontic adhesive primer which eliminates the need to etch the enamel (self-etching primer). In general, an acidic primer contains methacrylated (2-hydroxy methylmethacrylate and dimethacrylate) and phenyl phosphoric acid which etch and prime the enamel surface simultaneously [8]. The advantage of this procedure is reduced time, with fewer steps in the bonding process [9]. However, the clinical success with these products has not been proven due to the low bond strength [3,10,11]. Another drawback of self-etching primer is that the application is technique sensitive. It is not suitable for use in conditions where moisture is present [12]. In order to help solve such problems, manufacturers have developed hydrophilic primer.

Hydrophilic primer is an orthodontic adhesive primer that can be used in wet conditions. Most primers are hydrophobic and require that the enamel surface be completely dry after etching to allow penetration for adequate retention. Moisture contamination is known to reduce the bond strength and is a common reason for bond failure [13,14]. Moisture insensitive primer has been developed by the manufacturer to perform in the presence of moisture. It contains 2-hydroxyethyl methacrylate, polyalkenoate co-polymers with carboxylate groups and ethanol [15]. In a randomized controlled clinical trial, it was found that moisture insensitive primers have sufficient bond strength and are clinically efficient in moist conditions [16,17]. These studies suggest that moisture insensitive primers can be used to bond the brackets to the enamel surface in wet conditions with sufficient bond strength.

Lastly, the aim of this study was to determine the viscosity of different types of orthodontic adhesive primers. It is crucial to know the viscosity of each primer because it could affect the position of the bracket during orthodontic bond up. Apart from that, the effect of temperature towards viscosity was also studied because of the different temperatures in summer and winter.

Table 1: The composition of the orthodontic adhesive primers

Adhesive primers	Composition
Transbond XT primer (3M Unitek, Monrovia, CA, USA)	TEGDMA, Bis-GMA, 4-(dimethylamino)-benzeneethanol, DL-Camphorquinone, Hydroquinone
Unite primer (3M Unitek, Monrovia, CA, USA)	Triethylene glycol dimethacrylate (TEGDMA), Bisphenol A diglycidyl ether dimethacrylate (BisGMA), 2,2'-(P-Tolylimino) diethanol ,Poly(methyl methacrylate) (PMMA), 3-methacryloxypropyltrimethoxysilane
Transbond SEP (3M Unitek, Monrovia, CA, USA)	Methacrylate ester derivate, Water, DL-Camphorquinone, Dipotassiumhexafluorotitanate
Transbond MIP (3M Unitek, Monrovia, CA, USA)	Ethyl alcohol, BisGMA, 2-hydroxyethyl methacrylate, 2-hydroxy-1,3-dimethacryloxypropane, Copolymer of itaconic and acrylic acid ,Water, Diurethanedimethacrylate

Materials and Methods

Four different primers (Table 1) were selected for this study. A controlled stress rheometer (Carri-Med MKII, UK) with attached computer in flow mode with a cone and plate test configuration was used to measure the viscosity. A cone angle (θ) of 2° truncated cone and 2cm plate diameter was used, with space between the cone and plate set to 70 µm. The frequency used was 1 Hz and the time to reach the maximum torque (termed the interval time) was 5 minutes. The orthodontic adhesive primers were tested during ascent and descent of the controlled stress rheometer.

For each measurement, a fresh sample of primer was carefully dispensed onto the plate, so that there was minimal excess of the material around the edge and no bubble underneath the gap. The maximum torque for the Carri-Med controlled stress rheometer is 5 N*mm. However, for this study, the maximum torque was lowered to 0.04 N*mm and 0.2 N*mm (400 and 2000 dyne cm). Initial tests revealed that 400 dyne cm was sufficient for low viscosity liquid and 2000 dyne cm torque was sufficient for the medium viscosity. The initial tests were done by gradually reducing the amount of the torque. Having a large amount of torque will make the rheometer over spin and abort the test.

Two test temperatures were selected to study the primers, 25°C and 35°C. The temperature of the plate of the rheometer was controlled using a Peltier control system with fluid circulator. The temperature control system used internal microprocessors to control the temperature in the plate by determining the power and direction to Peltier system (heat pump thermo-electric effect). By controlling the level and direction of the electricity current, the temperature in the plate could be controlled up to ± 0.1°C. Moreover, a steady flow of water (1/2 liter per minute) from the reservoir container was used to remove the excessive heat.

Data collection was done using a computer attached to the Carri-Med controlled stress rheometer. Then, the data were used for statistical analysis using One-way ANOVA to compare between each orthodontic adhesive primer group.

Results

The findings showed that the primer with the lowest viscosity value was Transbond MIP (21.74 ± 1.50 MPa·s) and the most viscous primer was Transbond XT (192.20 ± 1.21 MPa·s). In general, this study showed the following order of viscosity of the primers: Transbond XT > Unite adhesive primer > Transbond SEP > Transbond MIP.

The findings showed that the viscosity for every orthodontic adhesive primer was reduced at higher temperatures. At 25°C and 35°C, Transbond XT was found to have the highest viscosity while Transbond MIP was the lowest among the adhesive primers (Table 2). The findings showed that there were sta-

Table 2: Comparison of mean viscosity of each primer at 25°C and 35°C

Primers	Ascent viscosity (MPa˙s)		Descent viscosity (MPa˙s)	
	25°C	35°C	25°C	35°C
Transbond XT	192.20 ± 1.21	104.10 ± 1.16	194.10 ± 1.30	104.90 ± 1.20
Unite primer	143.40 ± 2.17	103.44 ± 1.35	141.80 ± 2.15	101.32 ± 1.46
Transbond SEP	44.28 ± 3.09	27.85 ± 2.82	44.10 ± 3.07	28.17± 3.12
Transbond MIP	21.74 ± 1.50	17.67 ± 0.58	21.95 ± 1.18	18.14 ± 0.48

tistically significant differences between the viscosity of each orthodontic adhesive primer and between the two temperatures ($p = 0.005$). The initial yields for each orthodontic adhesive primer were also calculated as shown in Table 3.

Discussion

The aims of this study were to examine the viscosity of orthodontic adhesive primers and observe the influence of temperature on viscosity. A controlled stress rheometer (Carri-med MKII, UK) with a truncated cone and plate was used in this study. The rheometer was used to obtain the shear strain and shear rate values. These values were then utilized to calculate the viscosity and yield point of each orthodontic adhesive primer.

In this study, Transbond XT was found to be the most viscous primer and Transbond MIP the least viscous. Unite adhesive primer was the second most viscous primer followed by Transbond SEP. The viscosity of each orthodontic adhesive primer can be explained by the type and amount of the monomer used. This was similar to the finding of Beau *et al.* who noted that the type of monomer was directly responsible for the organic matrix viscosity [18]. The interaction between monomer molecules correlated with the value of viscosity [19]. In general, materials with large monomer molecules will have a higher viscosity while those with small molecules have a lower viscosity.

Table 3: Initial yield for orthodontic adhesive primers

Primers	25°C	35°C
Transbond XT	194.2	104.6
Unite adhesive primer	147.7	108.3
Transbond SEP	45.97	28.93
Transbond MIP	20.96	18.24

This is the reason why Transbond XT has the highest viscosity compared to the other primers in the study. Transbond XT contains 45-55% of Bisphenol A diglycidyl methacrylate (Bis-GMA) and 45%-55% of Triethylene glycol dimethacrylate (TEGDMA). Bis-GMA is a large molecule and have a high viscosity value at room temperature [20]. Material with high viscosity will be harder to manipulate and need to be diluted. Therefore, Bis-GMA needs to be diluted with low viscosity esters such as TEDMA to reduce the viscosity [21]. Transbond SEP and Transbond MIP were both have low viscosity compared to Transbond XT and Unite adhesive primers. This can be explained by the molecular properties of the monomers. Transbond SEP contains 75-85% Methacrylate ester and 15-25% of water. Methacrylate ester composed of methacrylate monomer group and phosphoric acid. The methacrylate monomer is a small molecule compared to TEDMA and thus has smaller viscosity value.

The viscosity of the orthodontic adhesive primer was also examined under different temperatures. In this study, each primer was tested with two different temperatures (25°C and 35°C). Statistical analysis using a two-sample t-test revealed that there was a statistically significant difference between the viscosity at the two different temperatures for each primer ($p = 0.005$). All orthodontic adhesive primers tested in this study exhibited lower viscosity at higher temperatures (from 25°C to 35°C). The result was in agreement with other studies that looked into the effect of temperature on viscosity. As in this study, the viscosity significantly decreased with the increase in temperature [22].

In this study, the viscosity of orthodontic adhesive primer was associated with the type and amount of monomer. The viscosity of each orthodontic adhesive primer was also found to be influenced by different temperature. Increases in the temperature resulted in reduced viscosity for each of the orthodontic adhesive primers.

Conclusions

This study showed that the viscosity of orthodontic adhesive primers was varied, with Transbond XT primer being the most viscous and Transbond MIP the least viscous. The Unite adhesive primer are less viscous than Transbond XT but more viscous than Transbond SEP. The viscosity of orthodontic adhesive primers also changed with temperatures. This could have an effect during orthodontic bond up in summer whereby brackets position could be changed due to the high viscosity.

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