The Effect of Different Pre-Treatment Methods on the Shear Bond Strength of Orthodontic Tubes: An *in vitro* Study

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***Abstract*—**Objective: This *in vitro* study aimed to evaluate the shear bond strength (SBS) of orthodontic tubes after different enamel pre-treatments. Materials and Methods: A total of 39 crown halves were randomly divided into 3 groups (n = 13). Group I (control group) was exposed to prophy paste (PP), 37% phosphoric acid (PA), and a self-etching primer (SEP). Group II received no prophylaxis, but only PA and SEP. Group III was exposed to PP and SEP. The SBS was used to evaluate the bond strength of the orthodontic tubes one year after bonding. One-way ANOVA and Tukey's post-hoc test were used to compare SBS values between the three groups. The statistical significance was set to 5%. Results: The difference in SBS values of groups I (36.672 ± 9.315 Mpa), II (34.242 ± 9.986 Mpa), and III (39.055 ± 5.565 Mpa) were not statistically significant ($P < 0.05$). Conclusion: This study suggests that chairside time can be significantly reduced with the use of PP and a SEP without compromising adhesion. Further evidence is needed by means of a split-mouth design trial.

***Keywords*—**Shear bond strength, orthodontic tubes, self-etching primer, pumice, prophy.

I. Introduction

The enamel bonding protocol has been utilised in dentistry for many decades. This bonding bonding protocol was first developed by Dr. Michael Buonocore in 1955 [1], which consisted of etching and priming the enamel in two different steps, with rinsing and drying in between. A more recent development in the enamel bonding technology is the use of a SEP which combines the action of etching and priming in a single step [2]. A preliminary step, that was also a part of Dr. Buonocore's protocol, is the use of a prophylactic cleaning agent such as pumice prophylaxis. The theory behind the use of this agent supports the need to remove any superficial material that may interfere with enamel etching and its bonding procedure [3]. This theory was validated by tests showing that enamel bond strength can potentially be strengthened by using pumice prophylaxis [4]. In the 1960s, Dr. George Newman extended the existing knowledge of enamel bonding to bond orthodontic brackets [5].

The ideal scenario in orthodontics is to achieve a bond that can be strong enough to withstand masticatory and orthodontic forces [6] without causing damage to the enamel. Such a bond must also be stable in a wet environment during the entire duration of treatment [5]. A few variables can influence the SBS of orthodontic brackets. For instance, tooth-related factors such as demineralization [7] and different pre-treatment methods can have a distinct impact on SBS [8]. Various forms of pre-treatments could increase the SBS of orthodontic brackets to demineralized enamel. Bonding to demineralized enamel that was pre-treated with resin infiltrant showed bond strengths similar to sound enamel [8].

In contemporary busy orthodontic practices, reducing the number of unnecessary steps can not only increase patient comfort, but also decrease chairside time. In this context, the use of pumice prophylaxis has caused enamel damage and increased chairside time [2], whereas the use of SEPs with expedited bonding have become quite popular in orthodontics [9]. In addition, SEPs have shown to cause less damage to the enamel, as well as reducing moisture sensitivity, and increasing efficiency in comparison to the conventional two-step etching method [10], [11].

A previous study showed that pre-etching with 37% PA before application of a SEP leads to higher SBS of orthodontic brackets. The same study also stated that the use of pumice prophylaxis may increase bond strength due to removal of the salivary pellicle [2]. The present study investigated the possibility of eliminating some of these bonding steps to reduce chairside time, yet not compromising the SBS. The hypothesis was that the elimination of either pumice prophylaxis or PA would not decrease the SBS values when bonding orthodontic tubes.

II. Materials and Methods

Specimen Preparation

A total of 20 sound human premolars that had been extracted for orthodontic reasons were utilized. These teeth were washed in running water and stored at room temperature (37 °C) in distilled water containing 0.2% thymol. Teeth with caries,

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restorations, cracks, and other defects such as hypoplasia or decalcification were excluded.

The roots and the coronal pulps were removed, and the crowns were split into two halves at the central groove, creating 40 half-crowns total. One half-crown was excluded, and 39 half-crowns were randomly divided into three groups (n = 13) according to the bonding methods and materials used (Tables I and II).

TABLE I
DENTAL MATERIALS USED IN THIS STUDY

Materials	Manufacture
Clinpro™ PP	3M Unitek, Monrovia, California, USA
37% *PA* gel	3M Unitek, Monrovia, California, USA
Transbond™ Plus SEP	3M Unitek, Monrovia, California, USA
Transbond ™ XT Light Cure Adhesive Primer (TXT)	3M Unitek, Monrovia, California, USA

TABLE II
ENAMEL PRE-TREATMENT METHODS

Groups	Methods
I	**PP + PA + SEP** + TXT Two-step pre-treatment
II	*PA* + **SEP** + TXT Two-step pre-treatment
III	**PP + SEP** + TXT One-step pre-treatment

Abbreviations: PA: 37% PA; SEP: Transbond™ Plus SEP; TXP: Transbond ™ XT Light Cure Adhesive Primer.

Bonding Procedure

39 lower second molar tubes (3M Unitek, Monrovia, California, USA - Victory Series™, Buccal Tubes, LR 2nd molar, 0.018”, 0.46 mm) were used in this study. They were bonded in the centre of the clinical crowns by the same operator, following the manufacturer’s instructions.

The buccal or palatal/lingual surfaces were stabilized on a red wax baseplate (BASEPLATE WAX, Henry Schein®, USA), and embedded into PVC rings (Carlon®, USA) using blue self-curing acrylic resin (Bosworth Fastray™, USA) leaving the crown surface exposed for bonding. The average surface area of the teeth was measured and equalized in all samples.

Prior to bonding, gross debris were removed using a conventional toothbrush and water. The specimens were stored in distilled water at a temperature of 37 °C for 24 hours.

The two-step method was performed in groups I and II. It consisted of etching with 37% PA gel for 15 seconds, rinsing for the same amount of time, and drying with oil-free compressed air for 3-5 seconds before SEP application. A gentle airburst was delivered to each bonding surface for 1-2 seconds to dry the primer to a thin film. Only group I was prepared with pumice prophylaxis prior to PA and SEP. After SEP surface treatment, Transbond XT (TXT) adhesive was homogeneously applied on the mesh of the second molar tubes before pressing them against the tooth surface until excess TXT adhesive was expelled. This excess adhesive was then removed with an explorer before light curing for 20 seconds. The single etching method was performed in group III and followed the use of pumice prophylaxis (Table II).

SBS Test

The tubes were debonded after storage in distilled water at 37 °C for one year. SBS was assessed with a computerized MDS Landmark® servohydraulic S-System (Eden Prairie, Minessota, USA). The machine was set and calibrated as per the manufacturer’s instructions. The samples were placed and aligned in the testing machine with the tube perpendicular to the plunger.

The force was applied parallel to the tooth surface on top of the orthodontic tube base so that the knife-edged blade could be loaded at the bracket-adhesive interface. The tubes were shear tested to failure using a load cell of 1000 N, and a crosshead speed of 5.0 mm/min. The force magnitude to induce failure was converted from Newton to force per unit area (Megapascal, MPa). The tube mesh surface area was approximately 10.037 mm^2.

Statistical Analysis

The statistical analysis was performed using OriginLab data analysis software (Northampton, Massachusetts, USA). The Shapiro–Wilk test confirmed normality and intergroup variance homogeneity. One-way ANOVA and Post-hoc tests were performed to compare intergroup SBS values. On all occasions, statistical significance was set at 5%.

III. RESULTS

The mean, standard deviation (SD), and range of the SBS values in Mpa are in Table III. Group III has a narrower range and a smaller SD than groups I and II. However, the mean value of all three groups is similar. There is no statistically significant difference between the groups ($\alpha = 0.5$).

TABLE III
DESCRIPTIVE STATISTICS

Groups tested	n	Mean (Mpa)	SD (MPa)	Range (MPa)
I	13	36.672	9.315	20.8 - 50.5
II	13	34.242	9.986	22.2 - 57.9
III	13	39.055	5.565	31.6 - 48.7

IV. DISCUSSION

SBS is usually the main variable to consider when evaluating the performance of a bonding material since brackets and tubes must withstand masticatory and orthodontic forces [12], and require a bond strength of approximately 6-8 MPa [13]. In this study, the SBS of orthodontic tubes with three different pre-treatment protocols were compared.

The use of SEPs to bond orthodontic brackets was found to yield clinically acceptable SBS values [9], [14]. SEPs have been widely used in orthodontics to streamline the bonding protocol, and three studies have already confirmed their efficiency: [10], [15], and [16]. Vilchis et al. [10], for example, used extracted human premolars to compare the SBS of orthodontic brackets bonded with four SEPs and adhesives including Transbond Plus and Transbond XT, 3M Unitek; Clearfil Mega Bond FA and Kurasper F, Kuraray Medical; Primers A and B, and BeautyOrtho Bond, Shofu; AdheSE and Heliosit Orthodontic, Ivoclar Vivadent AG. They concluded that all four combinations of SEPs and adhesives yielded SBS values higher than the clinically acceptable SBS for orthodontic brackets as suggested by Reynolds [13]. Similarly, Buyukyilmaz *et al.* [16] conducted an in vitro study to determine the effects of using three SEPs on the SBS of orthodontic brackets and on the bracket/adhesive failure mode. The brackets were bonded to extracted human teeth according to one of the four protocols. They concluded that the hybrid layer formed after application of the orthodontic SEP, Transbond Plus, did not reduce the bond strength of orthodontic brackets.

The SBS values in this study are considerably higher than those reported by [10] and [17]. This most likely reflects the fact that these authors measured SBS 24 hours after bonding, whereas samples were tested after one year in this study.

The SBS values in this study are similar among the three enamel surface preparation protocols with all groups showing an SBS higher than 30 MPa, which substantially suffices to withstand the demands of the oral cavity [13]. These results resemble those reported by [10] where pre-etching with PA or omitting this step before applying the SEP was not found to affect SBS. However, [17] observed higher SBS values when pre-etching with *PA*; however, their specimens were not pumiced whereas, the ones by [10] were pumiced.

A recent study has shown that PA pre-etching improves the chemisorption between enamel and methacryloyloxydecyl dihydrogen phosphate (MDP)-containing universal adhesives and offers more negative charge on the enamel surface compared to untreated enamel [18]. This study also found no advantage from pumicing the enamel when it is pre-etched with PA. The lack of statistically significant difference pointed to the redundancy of pumicing whenever PA is used. Abreu et al. [19] has similarly reported that the use of pumice prophylaxis did not significantly affect enamel roughness caused by acid etching and suggested that pumicing prior to acid etching may not significantly improve the bonding of orthodontic brackets and tubes.

Fitzgerald et al. [17] found statistically significant higher SBS values when pre-etching with PA was not preceded by pumicing. However, when only SEP was used (without the pumicing stage), it yielded the lowest values, supporting the use of an additional tooth surface preparation step to remove the salivary pellicle. Therefore, despite being recommended by the manufacturer of the Transbond^{TM} XT primer (3M Unitek, Monrovia, California, USA), pumicing seems to be unnecessary if PA pre-etching is performed. This surely is a clinically significant finding since pumicing can cause damage to the gingiva, protein contamination of the enamel from the disturbed gingival crevicular fluid, increased chair-side time, and its persistence on the tooth which can affect bonding [17].

This study and [10], both demonstrated that, as long as pumicing is performed, there is no need to pre-etch with PA. This was observed both after 24 hours [10] and 1 year after debonding. However, [17] showed that pumicing is necessary when no pre-etching is performed before the application of a SEP. Thus, pumicing before SEP application is an alternative to avoid risks offered by PA, such as enamel loss, tooth or composite resin discoloration, and oral mucosa irritation or corrosion [20], [21].

There are two confirmed methods when using SEPs in orthodontics: 1) pre-etching with PA without pumicing, and 2) pumicing without pre-etching with PA. In the former, a bitter acid, and in the latter, an abrasive material is used that will both require rinsing and drying. It is now in the hands of the clinician to take these facts into account and calculate the costs as well as the chairside time involved with each method.

Although *in vitro* studies are very important to guide clinicians in the selection of the best protocol for bonding orthodontic brackets and tubes, they have limitations related to the difficulty in properly mimicking the complex structure of the oral cavity. Therefore, further clinical studies are needed to confirm the present findings.

V. Conclusion

The hypothesis that the elimination of either pumice prophylaxis or PA would not lead to a decrease in SBS values, was accepted. This *in vitro* study suggests that pre-treatment with either 37% PA or pumice prophylaxis provides clinically acceptable SBS of self-etching adhesives used to bond orthodontic tubes. Future clinical studies are required to investigate the long-term *in vivo* performance of these bonding protocols.

Disclosure statement

The authors have no conflict of interest to declare.

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