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Residual pumice: assessing a potential contaminant in orthodontic bonding.

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ABSTRACT

Objective: To assess the effect of clinically-observed residual prophylaxis pumice on orthodontic shear bond strength when using a self-etching primer bonding protocol.

Materials and Methods: 100 bovine teeth were randomly divided into five groups (N=20) according to prophylaxis protocol: control (no pumice prophylaxis), pumice flour with mechanical debridement, pumice flour without debridement, pre-mixed pumice with mechanical debridement, and pre-mixed pumice without mechanical debridement. After prophylaxis, brackets were bonded using a self-etching primer bonding technique (3M Unitek Transbond Plus Self-Etching Primer). Samples were tested for bond strength 48 hours after bonding using a universal testing machine. Data were analyzed using analysis of variance (ANOVA) with significance level at 0.05.

Results: No significant differences were found between the five groups (p=0.09). Using a 2-factor ANOVA on the experimental groups, there was no statistically significant effect for the type of pumice (p=0.157), mechanical debridement (p=0.184), or their interaction (p=0.087).

Conclusions: When using a self-etching primer bonding protocol *in vitro*, orthodontic shear bond strengths are not influenced by the use of pumice prophylaxis, the tested formulations of pumice, or the presence of residual pumice clinically-observed on enamel prior to bonding.

INTRODUCTION

Considerable attention has been given to the effect of various enamel surface treatments on bond strength and bond failure rate of orthodontic brackets [1-6]. Though some research has suggested otherwise [7-10], a majority of the literature indicates that prophylaxis prior to etching the enamel surface aids in the removal of acquired pellicle and surface contaminants, reducing bond failure and increasing shear bond strength (SBS) with enamel, especially when using a self-etching primer (SEP) [11-15]. Additionally, bonding agent manufacturer's bonding protocols located in their respective instructions for use (IFUs) call for prophylaxis of the enamel surface with a prophy angle prior to etching [16,17]. Investigators have questioned whether ingredients contained within various prophy pastes, such as flavoring oils or fluoride, could potentially serve as contaminants that could negatively impact bond strength. Comparisons between these prophy pastes and oil-free, fluoride-free flour pumice in the context of resin bonding have largely shown no statistically significant difference in impact on SBS or bond failure [1,15,18,19], however some studies have shown otherwise [20]. Accordingly, research studies examining various influences on orthodontic bonding typically utilize pumice flour without the extra ingredients in their bonding protocols in order to eliminate them as a potential contaminant. Bonding agent IFUs also call for pumice without oils or fragrances, claiming that they inhibit the etching process [16,17]

In an attempt to deliver a more clinically convenient method of pumice prophylaxis, several companies have developed pre-mixed individual unit-dose packaged flour of pumice (i.e. Nada Pumice Paste, Preventech; Preppies, Whip Mix; Prophy Paste, Ortho Technology; Champion, DynaFlex; 1st & Final, Reliance Orthodontics Products, Inc.). One *in vitro* study has shown that there is no difference in bond strength after using a pre-mixed unit dose pumice flour versus a mixture of water and pumice flour [14]. In clinical practice, use of some pre-mixed pumice pastes can leave a residual film of pumice on the enamel surface even after copious rinsing with the air-water syringe that can sometimes only be visualized under magnification and/or adequate lighting. This clinical phenomenon has not been studied. A 2012 study by Fitzgerald et al. studied the effects of pumice prophylaxis and pre-etching on orthodontic SBS when using a SEP protocol. They unexpectedly found that the group that used pumice prophylaxis prior to pre-etching had lower SBS than the group that was not prophylaxed. As one of the possible explanations to this phenomenon, they suggested that despite rinsing, pumice may have remained on the tooth and affected bond strength [8].

In addition to rinsing, residual pumice on enamel surfaces may subsequently be removed by scaling or wiping with a cotton roll, followed by additional rinsing prior to recommencing the steps of etching and bonding. In cases where this residual pumice is overlooked due to lack of direct visualization, lighting, or magnification, the pumice may potentially be a resultant clinical contaminant that could influence resin bonding. Subsequent etching, priming, and bonding--with steps that involve additional rinsing and/or mechanical scrubbing with a micro-brush—may remove some or all of this residual pumice, negating its influence, however this variable has not been studied to date.

Prophylaxis with pumice prior to use of a self-etching primer appears to have the largest positive impact on reducing bond failure relative to bonding with a total etch system [12,13,15]. Additionally, self-etching primer manufacturer's IFUs include a prophylaxis step prior to using their products [17]. A self-etching primer bonding protocol was also selected for this study for its simplicity (i.e. fewer steps with reduced variability) as well as for its recent increase in use in clinical practice as a time-saving measure [21]. This *in vitro* study compared resin-enamel shear bond strengths of orthodontically bonded teeth. Samples were pre-treated with differing prophylaxis protocols and SEP in an attempt to assess the potential contaminating effect of residual prophylaxis pumice on orthodontic bond strength. It was hypothesized that residual pumice decreases bond strength when bonding orthodontic brackets with a self-etching primer protocol. The null hypothesis of this study therefore stated that residual pumice has no effect on the bond strength when using a self-etching primer orthodontic bonding protocol.

MATERIALS AND METHODS

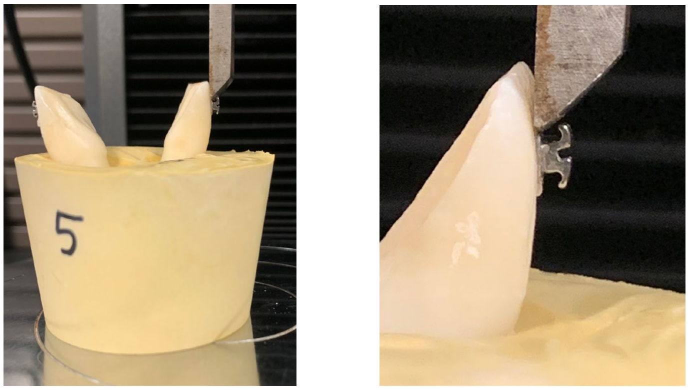
One hundred bovine teeth (Animal Technologies, Inc.; Tyler, TX) were stored on dry ice for shipping and subsequently a chloramine-T (chloroparatoluene sulfon-amide salt) solution until ready for study. Teeth were cleaned of debris with a sponge, rinsed with 0.9% Sodium Chloride irrigation saline solution, and then placed in synthetic saliva for 48 hours. The synthetic saliva solution was mixed according to the recipe by Lata et al.[22]: Na3PO4 – 3.90 mM, NaCl2 – 4.29 mM, KCl – 17.98 mM, CaCl2 – 1.10 mM, MgCl2 – 0.08 mM, H2SO4 – 0.50 mM, NaCHO3 – 3.27 mM, and distilled water with a pH set to a level of 7.2. The bovine teeth were randomly divided into 5 groups of 20 teeth each. Exclusion criteria of teeth included enamel fracture/defects, caries, or irregular/curved surface anatomy. 3M Unitek (Monrovia, CA) 0.022 MBT APC Victory tooth #8 brackets pre-coated with Transbond XT were bonded to every tooth using Transbond Plus Self Etching Primer (SEP) according to the Instructions for Use (IFUs)[17], with slight modifications to the protocol depending on their respective group. Teeth were prophylaxed for 5 seconds each using pumice and a prophy angle, then copiously irrigated with an air/water blast from a dental unit 3-way air/water syringe for 3 seconds. Excess water was removed from the tooth surface using oil-free, compressed air from an air/water syringe, being careful not to dry out the tooth surface. A microbrush saturated with Transbond Plus SEP was used to rub each tooth surface with gentle pressure for 5 seconds per tooth. The microbrushes were re-dipped into SEP before rubbing the next tooth, and a new SEP unit was used after application on 10 teeth (manufacturer recommends a new unit for every arch treated, or ~14 teeth). Air from the air/water syringe was used to gently deliver a burst of air for 2 seconds for each tooth to dry the primer into a thin film. Brackets were immediately bonded to the teeth, pressed firmly onto the center of the facial surface of the tooth, accounting for the direction of force of the Instron Universal Testing machine (Norwood, MA). Excess flash was removed with a scaler. A VALO Ortho light cure (Ultradent; South Jordan, Utah) was applied using the "Xtra power" setting for 6 seconds on the mesial and 6 seconds on the distal sides of each bracket. Modifications to the protocol above for each of the five groups were as follows:

- Group "C" was not treated with any type of pumice prior to bonding, and served as the control group.
- Group "PF-*" was prophylaxed with a medium-grit pumice flour (Whip Mix; Louisville, KY) paste** and irrigated prior to bonding. This pumice flour paste was selected in this study due to its common use in clinical practice and due to the fact that it contains no additives (e.g. flavoring, oils, fluoride, glycerin).
- Group "PF+" was prophylaxed with the pumice flour paste and irrigated with water from the 3-way air/water syringe. To ensure removal of residual pumice, the enamel surface was then scaled, wiped with a cotton roll, and then re-irrigated prior to bonding**.
- Group "PMP-" was prophylaxed with a medium-grit pre-mixed pumice paste (Preppies, Whip Mix; Louisville, KY) and irrigated prior to bonding. This pre-mixed pumice paste was selected due to its common use in clinical practice, minimal additives, and most importantly, due to the clinically-observed phenomenon of leaving a residual pumice layer on enamel after rinsing.
- Group "PMP+" was prophylaxed with the pre-mixed pumice paste and irrigated with water from the 3-way air/water syringe. To ensure removal of residual pumice, the enamel surface was then scaled, wiped with a cotton roll, then re-irrigated prior to bonding.

**"+" denotes mechanical debridement of residual pumice, "-" denotes NO mechanical debridement of residual pumice. "PF" denotes pumice flour and "PMP" denotes pre-mixed pumice.*

***Ratio of paste is 1:2 water to pumice for all pumice flour paste.*

Fig 1a. **Fig 1b.**



Testing shear bond strength of the brackets bonded in the above groups was accomplished by mounting bovine teeth in yellow “buff” lab stone pucks, then placing them in the Instron Universal Testing machine (Model 5943, Instron, Norwood, MA)(Fig 1a. and 1b.). Debonding was completed 48 hours after bonding. Using the Instron machine, a force was applied to the base of the bracket at a rate of 1mm/min until bond failure was reached. The force recorded by the Instron at moment of bond failure was subsequently divided by the area of the bracket base (10.52 mm^2), representing the SBS of the bracket in megapascals (MPa). All steps of the bonding and debonding were performed by the primary investigator to eliminate inter-operator error.

DATA ANALYSIS

A priori power analysis using the F test for Analysis of Variance (ANOVA) to detect a medium effect (f = 0.37) indicated that a total sample of 100 (20 per group) would provide an overall power of 80% with alpha value at .05. Shear bond strengths of each group were calculated as means with standard deviations. Significant differences of SBS between the groups were analyzed using one-way ANOVA. The test groups (PF-, PF+, PMP-, and PMP+) were analyzed separately using a two-factor ANOVA (presence of debridement and pumice type). Statistical software (SPSS Inc., Chicago, Illinois, USA and SAS Institute Inc., Cary, North Carolina, USA) was used for analysis.

RESULTS

Mean shear bond strengths of all groups are listed in Table 1.

Table 1. Shear Bond Strength Test Results

Group	Mean Shear Bond Strength (Mpa)	Standard Deviation	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	N
C	11.17	4.39	9.19	13.15	20
PF-	11.66	3.31	9.68	13.65	20

PF+	14.75	5.67	12.764	16.73	20
PMP-	11.97	5.17	9.99	13.95	20
PMP+	11.57	3.25	9.59	13.55	20

The one-way ANOVA indicated that there was no statistically significant difference between shear bond strengths of the 5 groups (p=0.09). The two-factor ANOVA indicated that there is no statistically significant effect on SBS by the type of pumice (p=0.157), presence of debridement (p=0.184), or their interaction (p=0.087).

DISCUSSION

The null hypothesis that residual pumice has no effect on the bond strength when using a self-etching primer orthodontic bonding protocol could not be rejected. After preparing the enamel surface with the pre-mixed pumice, portions of the surface on many of the treated teeth indeed exhibited visible residual pumice after rinsing. These portions may or may not have coincided with the targeted location of bracket bonding, but nevertheless replicated the residual pumice phenomenon observed clinically. The phenomenon was not observed while using the pumice flour mixture. In the PMP- group where no attempt was made to physically debride the enamel surface prior to using the SEP, after subsequent treatment with SEP, no residual pumice was visualized at the treated sites. This fact, taken together with the lack of significant difference in bond strengths between groups, suggests that the use of the microbrush to apply the SEP likely served as a form of physical debridement that removed any residual pumice adhering to the enamel surface. Of course, it cannot be ruled out that varying amounts of residual pumice may have been present on a microscopic level in any of the test groups even after rinsing, debriding, and treating with SEP. Given the lack of difference in SBS between groups, the effect of this hypothetical microscopic residual pumice was negligible.

The shear bond strengths found in this study were higher than those required to withstand orthodontic forces and mastication (5.9-7.8 MPa)[23], and comparable to those found in similar SBS studies involving SEP [8,14,15,24]. However, According to Fitzgerald et al., comparing SBS values between studies is problematic due to variation in methodological and testing parameters, and intra-study group comparisons of SBS are most valid[8]. While the PF+ group had the highest mean SBS of any group (14.75 MPa), the mean SBS of that group did not have a statistically or likely clinically significant difference relative to the mean shear bond strengths of the other groups (11-12 MPa).

This *in vitro* study did not take into account the factors inherent in an *in vivo*, clinical study including moisture control/isolation, time, cyclic loading, patient behavior, and likely most important, acquired pellicle. *In vivo* studies have shown that pumice prophylaxis prior to using self-etching primer significantly reduces bond failure rate, and in the case of the 2008 study by Lill et al. using Transbond Plus SEP, up to five-fold[12,13]. The lack of plaque, detritus, and acquired pellicle on the bovine teeth in this study likely explains the similar bond strengths between the test groups and the un-pumiced control group. This hypothesis is supported by the *in vitro* studies by Fitzgerald et al. and Gultz et al., who stored test teeth in human whole saliva prior to bonding to promote pellicle formation. Their studies found that pumice prophylaxis prior to bonding with Transbond Plus SEP yields higher SBS than without prophylaxis[8,14]. The present study also agrees with the findings of Gultz et al. and Mahajan et al, in that there was no statistically significant difference in SBS when using pre-mixed versus pumice flour in a SEP orthodontic bonding protocol[14,15]. However, to definitively assess the clinical significance versus insignificance of residual pumice when using SEP on a patient, an *in vivo* study on bond failure rates similar to that of Lill et al. (2008) would be required[13].

CONCLUSION

This *in vitro* study concluded that shear bond strengths are not influenced by

1. The use of pumice prophylaxis.
2. The tested formulations of pumice (pumice flour paste versus pre-mixed pumice paste).
3. The presence of residual pumice clinically-observed on enamel prior to bonding with self-etching primer.

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