The effect of topical fluoride varnish on the shear bond strength of orthodontic brackets

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Aim: The present study examined the effect of topical fluoride treatment on the shear bond strength (SBS) of orthodontic brackets using single-dose fluoride varnishes and assessed according to different post-application times and the pattern of debond.
Methods: Of the 105 extracted human mandibular premolars used in the study, 70 were subjected to the SBS test and the remaining 35 to the Adhesive Remnant Index (ARI) test. The teeth were divided into a control group and six test groups: Kolorz® ClearShield™ 5% NaFl varnish Day 1, 8, and 15; and VanishTM 5% NaFl varnish Day 1, 8, and 15. The samples were coated with their respective varnish, following which, brackets were bonded. Each specimen was subjected to a shear force in a universal testing machine until failure. Data were analysed using the analysis of variance (ANOVA).
Results: At all time intervals, the mean SBS of the Vanish groups was not significantly different from the control group, and the shear strength in the ClearShield groups was significantly higher than the control and Vanish groups, except at Day 8 (no difference). For the same bonding material, there was no significant difference in mean SBS over different time intervals. ARI scores showed no significant difference between the groups.
Conclusion: The application of single-dose fluoride varnish, irrespective of the length of time between the fluoride treatment and bonding procedure, does not negatively affect the shear bond strength of orthodontic brackets.
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Introduction

Bracket bond failure is a frustrating issue that orthodontists encounter. The average bond failure rate for practitioners in the United States reported in 2004 was approximately 5%.[1] Bond failure inconveniences the patient and the orthodontic practice due to the additional cost, appointments and treatment time. It has been reported that a single bond failure may result in a 20–30 minute increase in appointment time and a cost of $70–80 to the practice.[2]

The causes of bond failure at the enamel surface include technique error, moisture contamination, excessive mechanical forces, the patient's care during treatment, and the integrity of the enamel surface prior to bonding.[3] Previous studies have shown that fluoride treatment prior to the bonding procedure may negatively affect bond strength.[4-6]

Fluoride treatment has been reported to enhance the enamel's resistance to acid etching.[4,5] It may be speculated that a less soluble enamel surface and a higher resistance to acid etching could lead to a decrease in bond strength. The use of topical fluorides prior to clinical procedures such as the application of fissure sealants, acid etch-composite restorations and the direct attachment of orthodontic brackets has not been recommended.[4] A study by Choi et al. showed that pretreatment with acidulated phosphate fluoride (APF) decreased the formation of microporosities or surface roughness in the enamel, and it was recommended that an acid-etching procedure should

be applied no sooner than two weeks after the application of APF.[5]

Recently, an in vivo split mouth study by Talic et al. assessed the effect on the clinical bond failure rates of using fluoridated prophylaxis paste compared with plain pumice.[6] Two quadrants of the mouth were prepared with a fluoridated paste and the other two quadrants were prepared with plain pumice before bonding with resin pre-coated brackets. It was found that enamel preparation with fluoridated prophylaxis paste resulted in a significant increase in the failure rate and decreased the survival time of the brackets.[6]

Contrary to the results of previous reports, additional research has suggested that the topical administration of fluoride has little or no effect on enamel bond strength.[7-9] Kimura et al. assessed the effect of fluoride varnish on the in vitro bond strength of orthodontic brackets using a self-etching primer system.[10] The results showed no appreciable difference in bond strength of orthodontic brackets attached to enamel treated with and without fluoride varnish. Similarly, a recent unpublished study by Nguyen et al. found that 2% NaF topical fluoride did not affect the shear bond strength of brackets.[11] Furthermore, the study also revealed that, even though SBS increased as the time between the application of fluoride and bonding of brackets increased, there were no statistically significant differences between the groups, and that all mean SBS levels were above the minimum requirements for clinical use.

Topical fluoride is commercially available in several forms and concentrations. Fluoride-containing varnishes were developed over 40 years ago in an effort to lengthen fluoride contact time with enamel[12] and allow for greater fluoride uptake. Based on this property of fluoride varnish and its popular use today, as well as the inconsistent results from previous studies, the objective of the present study was to further examine the effect of applied topical fluoride on the shear bond strength of orthodontic brackets. Unlike many previous studies in which Duraphat® 5% NaFl varnish (Colgate Oral Pharmaceuticals, NY, USA) was primarily used, the present study tested two products that are currently popular and have not been investigated. Vanish™ (3M ESPE, MN, USA) and Kolorz® ClearShield™ (DMG America, NJ, USA) are unit-dose 5% NaFl varnishes. Unit-dose packaging ensures convenience and fluoride dosage consistency.

The aim of the present study was to examine the effect of topical fluoride varnish on the SBS of orthodontic brackets at different post-fluoride application time intervals. A further aim was to evaluate the resin debond pattern using the Adhesive Remnant Index (ARI) based on the four-point scale of Årtun and Bergland.[13] It was hypothesised that teeth treated with fluoride varnish prior to the bonding of orthodontic brackets would exhibit a decreased shear bond strength and that brackets bonded to teeth treated with fluoride varnish soon after its application (one day) would exhibit the weakest bond strength.

Materials and methods

To examine the effect of topical fluoride varnish, 70 extracted human mandibular premolars were used, free of any visible buccal surface defects and restorations. The teeth were divided into six test groups and a control group (N = 10). The buccal surfaces of all teeth were cleaned with non-fluoridated prophylaxis paste and stored in distilled water. The teeth from Group 1 were coated once with Vanish™ varnish (3M ESPE, MN, USA) and Group 2 with Kolorz® ClearShield™ varnish (DMG America, NJ, USA) following the manufacturers' instructions and suspended immediately in synthetic saliva at 37°C for either one day, eight days, or 15 days prior to bracket bonding (Group A, Group B, and Group C, respectively).

After storage for the required time periods, the buccal surfaces of the premolars were cleaned with oil and fluoride-free pumice, rinsed with water and lightly air-dried for three seconds. Transbond™ XT Plus self-etching primer (3M Unitek, CA, USA) was applied to the teeth with light continued pressure for five seconds. An oil and moisture free air source was used to gently dry the primer into a thin film, after which Transbond™ XT Adhesive (3M Unitek, CA, USA) was added to Ormesh® Universal Mini-Twin bracket (Ormco, CA, USA) in a thin layer and pressed firmly until excess adhesive extruded onto the tooth surface. The excess adhesive was carefully removed and the adhesive was light cured using Ortholux™ Luminous Curing Light (3M Unitek, CA, USA) for 40 seconds (ten seconds on each side; mesial, distal, occlusal, and gingival) at a distance of 2–3 mm from the brackets. Each group was then stored in synthetic saliva at 37°C for 24 hours before debond.

To ensure that all brackets were debonded at the same angulation, the sample teeth were ligated to a

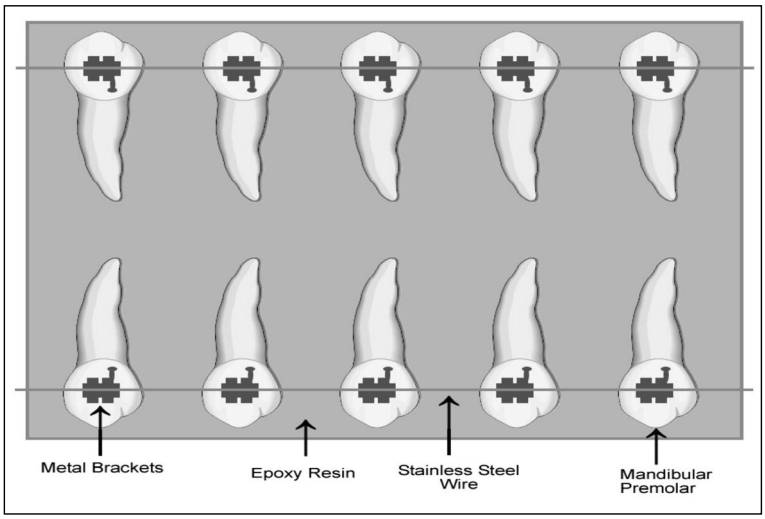

Figure 1. Samples set in epoxy resin.

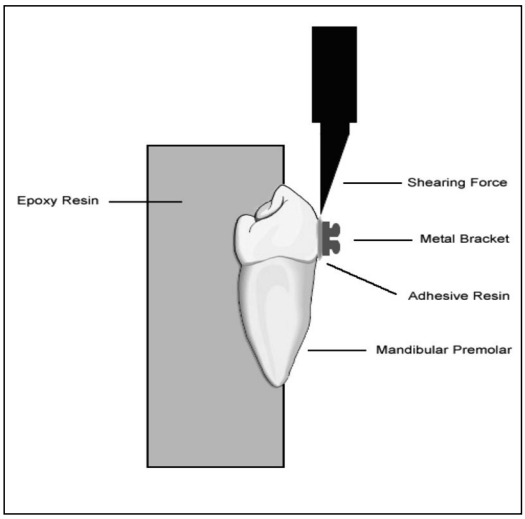

Figure 2. Mounting of sample.

0.019 × 0.025 stainless steel wire in groups of five teeth. Two wires were fixed to a rectangular container for a total of 10 teeth per container. Epoxy resin was added to the containers to a level that left the buccal surfaces exposed (Figure 1). The wires were removed once the epoxy hardened.

The blocks of epoxy resin containing the embedded teeth were mounted on a custom apparatus and secured on an Instron® 5566 universal test machine (Instron Corporation, MA, USA). An occlusal load with a crosshead speed of 1 mm/min was applied to each bracket, which produced a shear force at the bracket-tooth interface (Figure 2). The load applied at bracket bond failure was recorded. Shear bond strengths were calculated by dividing the load force (Newtons) by the bracket base area (mm^2). The base surface area of the brackets was 10.7 mm^2.

To evaluate the amount of the residual adhesive after bracket debonding, 35 extracted teeth were divided into six test groups and a control group (N = five). The samples were treated and prepared for debond in the same manner as described for the SBS test. The brackets for ARI scoring were debonded using an ETM buccal debonding plier (Ormco®, CA, USA). A tensile force was applied by grasping the bracket and pivoting the plier about an axis approximating the long axis of the tooth until the bracket detached from the enamel surface. Following attachment removal, all enamel surfaces and brackets were evaluated with 2.5x binocular loupes (Heine®, Herrsching, Germany) for ARI scoring (Table I).

Results

The results of the two-way ANOVA analysis comparing the SBS of orthodontic brackets bonded to teeth with and without fluoride varnish at different time intervals are shown in Table II. The analysis revealed that, at all time intervals, the mean SBS of the ClearShield groups were significantly higher than that of the control group ($p = 0.0172$, $p = 0.0240$, $p < 0.0001$) and that the mean SBS of the Vanish groups was not significantly different from that of the control group ($p = 0.9567$, $p = 0.9640$, $p = 1$). A comparison of the mean SBS between the two Vanish groups, at Day 1 and Day 15, revealed that the mean SBS of the ClearShield groups was significantly higher than that of the Vanish groups ($p = 0.0013$, $p < 0.0001$); however, there was no significant difference between the two varnish groups at Day 8 ($p = 0.2603$). For the same fluoride varnish, there was no significant difference in mean SBS over different time periods. The frequency distribution and results of the 1-way ANOVA analysis of the ARI are provided in Table III. The analysis demonstrated that there were no

Table I. Adhesive remnant index (ARI).

Scores	Adhesive remnant index
0	All adhesive left on the bracket base
1	More than 50% of the adhesive left on the bracket base
2	Less than 50% of the adhesive left on the bracket base
3	No adhesive left on the bracket base

Table II. *p*-value of 2-way ANOVA comparing shear bond strength of experimental groups.

	Control	ClearShield Day 1	ClearShield Day 8	ClearShield Day 15	Vanish Day 1	Vanish Day 8	Vanish Day 15
Control	——	0.0172	0.0240	< 0.0001	0.9567	0.9640	1.0000
ClearShield Day 1	0.0172	——	0.9999	0.2995	0.0013	0.1861	0.0216
ClearShield Day 8	0.0240	0.9999	——	0.1296	0.0016	0.2603	0.0302
ClearShield Day 15	< 0.0001	0.2995	0.1296	——	< 0.0001	0.0003	< 0.0001
Vanish Day 1	0.9567	0.0013	0.0016	< 0.0001	——	0.5076	0.9368
Vanish Day 8	0.9640	0.1861	0.2603	0.0003	0.5076	——	0.9772
Vanish Day 15	1.0000	0.0216	0.0302	< 0.0001	0.9368	0.9772	——

Significance level of 0.05

Table III. Frequency distribution and mean of adhesive remnant index (ARI).

	ARI scores				Mean
Group (N = 5)	0	1	2	3	
Control	1	2	1	1	1.4
ClearShield Day 1	2	0	2	1	1.4
ClearShield Day 8	0	2	2	1	1.8
ClearShield Day 15	1	2	1	1	1.4
Vanish Day 1	2	3	0	0	0.6
Vanish Day 8	0	2	2	1	1.8
Vanish Day 15	0	3	2	0	1.4

$x^2 = 5.666$; $p = 0.484$

significant differences in ARI scores between different materials and time points ($p = 0.484$).

Discussion

Many studies have shown conflicting results regarding the effect of topical fluoride application on the bonding strength of orthodontic brackets.[4-11] With the recent increase in the use of a single-dose fluoride varnish, an unanswered question was whether this form of fluoride would have an effect on the shear bond strength of orthodontic brackets. Fluoride varnish was produced in an effort to prolong the contact time between the fluoride ions and the enamel surface, to facilitate a greater ion uptake.[12] The fluoride ions encourage the formation of fluoroapatite crystals, which has been shown to increase the micro-hardness of enamel, as well as reduce its solubility in the presence of increased oral acidity. Generally, teeth with a higher concentration of fluoride are more resistant to acid etching and can require a longer etching time.

The hypothesis that teeth treated with fluoride varnish prior to the bonding of orthodontic brackets would exhibit a decreased shear bond strength, and that brackets bonded to teeth treated with the varnish soon after application (after one day) would exhibit the weakest bond strength, was rejected. The results of the present study suggested that the tested fluoride varnish products did not negatively effect (or decrease) the bond strength of orthodontic brackets, even if the brackets were bonded as soon as 24 hours after varnish application. It was noteworthy that the application of Kolorz® ClearShield™ varnish, prior to bracket bonding, yielded significantly greater bond strength when compared with the control group. The mean shear bond strength of all experimental groups (Table IV) was found to exceed the minimum of 6 to 8 MPa required for adequate clinical performance.[14] The reason for the difference in bond strength between the two test products is unknown. Since the bonding procedure was the same for both products, speculation would logically focus on the component differences between the two materials. According

Table IV. Means (standard deviations), minimum and maximum shear bond strength values (MPa) without possible outliers.

Group (N = 10)	Mean (SD)	Max	Min
Control	9.023 (1.83)	11.610	5.786
ClearShield Day 1	13.282 (4.55)	22.944	6.554
ClearShield Day 8	12.901 (2.31)	16.808	10.127
ClearShield Day 15	16.174 (1.88)	18.983	13.333
Vanish Day 1	7.855 (2.58)	13.850	5.514
Vanish Day 8	10.148 (1.21)	12.718	8.747
Vanish Day 15	9.123 (1.77)	12.345	5.614

to the Medical Safety Data Sheets (MSDS) for the products, Vanish™ contains tricalcium phosphate, hexane and a lower alcohol content compared with ClearShield™. Further investigation is required to determine if any of these component differences affect bond strength.

The results of the present study agree with recent findings which suggest that the topical administration of fluoride has little or no effect on enamel bond strength.[6-9] In an in vitro study by Kimura et al., the effect of fluoride varnish (Cavity Shield, Omni II Oral Pharmaceuticals, FL, USA) on the bond strength of orthodontic brackets using either conventional or self-etching primer systems was evaluated.[10] The samples (extracted human premolars) were prepared and placed in synthetic saliva for 10 days prior to the bonding procedure. The results showed no difference in bond strength of orthodontic brackets attached to enamel treated with and without the fluoride varnish, with the mean shear bond strengths ranging from 13.2–16.2 MPa.

With no concerns regarding the negative effect of topical fluoride on bond strength, its application immediately before and during orthodontic treatment may provide benefits for patients who are at risk of developing white spot lesions. At-risk patients may show clinically visible white spot lesions as early as four weeks after the placement of fixed appliances.[15] The lesions can be present at the first adjustment visit; therefore, prevention is imperative. Orthodontic patients with existing demineralised enamel may derive greater benefits from fluoride application prior to the placement of fixed appliances. A recent study by Moosavi et al. found that the application of 2% NaFl gel for four minutes before acid etching has the ability to reduce the amount of micro-leakage under orthodontic brackets while promoting re-mineralisation of the underlying lesions in teeth exhibiting hypomineralised defects.[16]

Clinical trials are necessary to validate the laboratory assessment of bond strength studies because of criticism related to their reliability and clinical relevance.[17] The limitations are intrinsic and expected because of the range of bracket systems used clinically.[10] In addition, the inability to guarantee the precise distribution of stress at the bracket-adhesive interface for each sample adds to the limitations of this in vitro study.

Conclusions

Under the conditions of the present in vitro study, the results suggested that the application of a single-dose fluoride varnish, irrespective of the length of time between the fluoride treatment and bonding procedure, did not reduce the bond strength of orthodontic brackets to enamel. There were no significant differences in the ARI scores between the test groups.

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