Original Research

In vitro Effects of a Neutral Fluoride Agent on Shear Bond Strength and Microleakage of Orthodontic Brackets

Farzaneh Ahrari [1], Zahra Sadat Hosseini [2], Nadia Hasanzadeh [1], Majid Ghanbarzadeh [1]

[1] Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

[2] School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

Received 22 February 2014 and Accepted 12 May 2014

Abstract

Introduction: This study aimed to evaluate the effect of pretreatment with a neutral fluoride agent on shear bond strength (SBS) and microleakage of orthodontic brackets, and to investigate any significant relationship between SBS and microleakage. **Methods:** Forty intact premolars were selected and randomly divided into 2 groups. Group 1 served as the control, while group 2 underwent treatment with a 2% sodium fluoride (NaF) gel, which was applied on the enamel surface for 4 minutes before etching. After bonding orthodontic brackets, the teeth were immersed for 12 hours in methylen blue dye, followed by mounting in acrylic resin. Shear bond strength was determined using an Instron Universal Testing Machine and the amount of microleakage and the adhesive remnant index (ARI) were assessed under a stereomicroscope. **Results:** The mean SBS and microleakage beneath metal brackets were not significantly different among the control and NaF-treated groups ($P>0.05$). Furthermore, no significant correlation was found between SBS and microleakage ($r=-0.04$, $P=0.796$). The ARI scores revealed that in both groups, most of the adhesive remained on the enamel surface after debonding. **Conclusions:** It may be concluded that pretreatment of enamel with 2% NaF prior to the bonding procedure does not significantly affect microleakage and SBS of orthodontic brackets and thus, it can be recommended as a suitable approach to reduce the incidence of white spot lesions in orthodontically treated patients, especially those at high risk of caries formation.

Key words: Bonding, bond strength, microleakage, orthodontics, sodium fluoride.

Ahrari F, Hosseini ZS, Hasanzadeh N, Ghanbarzadeh M. *In vitro* Effects of a Neutral Fluoride Agent on Shear Bond Strength and Microleakage of Orthodontic Brackets. J Dent Mater Tech 2014;3(3):106-11.

Introduction

Enamel decalcification or the formation of white spot lesions has been identified as a significant problem in patients undergoing fixed orthodontic treatment (1,2). Enamel decalcification has been reported in as many as 50% of the teeth bonded with orthodontic brackets and in up to 50% of orthodontic patients (3,4).

Fluoride is an important adjunct in the prevention and treatment of initial caries lesions and its application has been recommended in different phases of orthodontic treatment. When sound enamel is exposed to topical fluoride agents such as concentrated varnishes or gels, the reaction products form a calcium fluoride layer (CaF_2) on the enamel surface. Surface coatings may prevent both initiation and progression of enamel caries by acting as diffusion barriers, reducing enamel solubility and desorbing microorganisms from the enamel surface (5,6).

The application of fluoride compounds prior to, following, or in combination with acid-etching has been suggested as a means of providing rapid uptake of high levels of fluoride into enamel, resulting in higher fluoride content in fluoride-treated acid-etched enamel compared to that of the fluoride-treated sound enamel (7,8). Furthermore, Hicks et al. (8) and Chow and Brown (9) reported that the etching patterns observed in fluoride-treated acid etched enamel were similar to those found in normally-etched enamel, and were considered to be acceptable for resin placement.

In clinical orthodontics, it is essential to establish reliable bond strength between enamel and orthodontic attachments. Since the adhesion between enamel and adhesive resin is remarkably dependent on enamel surface properties (5), it is possible that enamel pre-treatment with fluoride, which induces fluoride deposition on the surface, interferes with the bonding mechanism of resins, and thus affecting the bond strength of orthodontic brackets (10). It may also affect the occurrence of microleakage under orthodontic brackets by affecting the adequacy of adhesive adhesion to tooth structure.

Previous studies reported controversial findings regarding the effect of topical fluoride agents on shear bond strength (SBS) of orthodontic brackets. While some authors presented significant changes in SBS values (11,12), others reported that fluoride did not compromise the bracket bond strength (10,13-15). Furthermore, to the best of the authors' knowledge, there is no study regarding the effect of topical fluoride therapy on microleakage under orthodontic brackets bonded to sound enamel. Therefore, the aim of the present investigation was to evaluate the effect of a 2% neutral sodium fluoride gel before the bonding procedure on SBS, bond failure mode, and microleakage of orthodontic brackets, and to determine any significant relationship between SBS and microleakage.

Materials and Methods

In this study, forty human premolars which had been extracted for orthodontic purposes were used. The buccal surfaces of the teeth were intact and without any hypoplasia or enamel cracks. The specimens were stored in a 0.2% (wt/vol) thymol solution for two weeks in order to inhibit bacterial growth and then stored in normal saline solution until the time of the experiment. The teeth were randomly divided into 2 groups and 20 teeth were assigned to each group. Before bracket bonding, the buccal surfaces of the teeth were cleaned with fluoride-free pumice slurry and rubber prophylactic cups for 5 seconds, then rinsed with water and air-dried. Stainless steel pre-adjusted edgewise upper premolar brackets (0.022-inch slot; Dentsply GAC International, Bohemia, NY, USA) were used in this study.

In group 1 (control), the sound enamel surface was covered with a 37% phosphoric acid gel for 30 seconds. The teeth were rinsed with a copious amount of water, and dried with an oil-free air source. Then, a thin coat of Transbond XT primer (3M Unitek, Monrovia, California, USA) was painted on the enamel surface and the bracket was placed at the middle of the crown with the use of Transbond XT adhesive (3M Unitek). The excess composite was removed from the periphery of the base with a dental explorer and the bracket was light cured for 10 seconds from each of the occlusal, gingival, mesial and distal directions (40 seconds in total) using Bluephase C8 (Ivoclar Vivadent, Schaan, Liechtenstein) light-emitting diode (LED) at power density of 650 mW/cm^2.

In group 2 (NaF), a 2% neutral sodium fluoride gel (Sultan Healthcare Inc., Englewood, New Jersey, USA) was applied on the enamel surface for 4 minutes. Then, the teeth were rinsed for two consecutive periods of 5 minutes each to remove any reaction products (8). A 37% phosphoric acid gel was later applied on the surface and the bonding procedure was followed similar to the control group.

The bonded teeth were kept in distilled water for at least 24 hours at 37˚C and then thermocycled between 5ºC to 55º C for 500 cycles with dwell time of 30 seconds per bath. The dye penetration technique was used for microleakage assessment. The apices of the teeth were sealed with sticky wax and the entire surfaces of the teeth were covered with two layers of nail varnish up to 1 mm around the brackets. The teeth were then exposed to a solution of 1% methylene blue dye for 12 hours, followed by thorough rinsing with tap water. The specimens were mounted in self curing acrylic resin in such a way that the buccal surfaces of the teeth were parallel to the direction of the debonding force.

Shear bond strength (SBS) test was performed by an Instron Universal testing machine (Santam, model STM-20, Iran), using cross head speed of 1 mm per minute until failure. The force required to fracture the bracket-tooth interface was recorded in newtons and then converted to megapascals (N/mm^2) by dividing the force value by the area of the bracket base (13.1 mm^2).

After debonding, the teeth were assessed under a stereomicroscope (Dino-Lite Pro, Anmo Electronics Corp, Taiwan) at 20 X magnification by a calibrated investigator. Microleakage was assessed by measuring the deepest penetration of the dye under the brackets (mm) perpendicular to the bracket margin. The investigator repeated the measurement on 20% of the specimens one week later to determine the intra-examiner error.

The teeth and brackets were also examined at 10 X magnification to evaluate the bond failure mode, based on the amount of remaining adhesive on the enamel surface. The adhesive remnant index (ARI) of Artun and Bergland (16) was used for scoring: 0 indicated that no adhesive remained on the tooth; 1 indicated that less than 50% of the adhesive was left on the tooth; 2 displayed that more than 50% of the adhesive remained on the tooth; 3 indicated that all the adhesive remained on the tooth, with distinct impression of the bracket mesh.

The data were analyzed for normality by means of the Kolmogorov-Smirnov test. The measurement error and the systemic error of the two microleakage assessments were determined by the Dahlberg formula and Wilcoxon signed rank test, respectively. An independent-samples t-test was run to detect any significant difference in SBS values between the study groups. The amount of microleakage was compared among the two groups by Mann–Whitney *U*-test and the difference in ARI scores was assessed by the chi-square test. The Spearman's rank correlation test was used to determine any relationship between microleakage and bond strength. The data were analyzed by the SPSS (Statistical Package for Social Sciences, Version 11.5, Chicago, Illinois, USA) software and the level of significance was set at $P<0.05$.

Results

The systemic error was not significant between the two microleakage assessments (P=0.117) with a measurement error of 0.31 mm.

Tables 1 and 2 present the descriptive statistics including mean, standard deviation (SD) and range regarding SBS (MPa) and microleakage (mm) of the study groups, respectively. The independent-samples t-test exhibited no significant difference in bond strength values between the control and NaF-treated groups (P=0.589, Table 1). In both groups, some degree of microleakage occurred beneath the brackets, as illustrated in Fig. 1. The statistical comparison of microleakage scores using Mann–Whitney U-test indicated no significant difference between the two study groups (P=0.258, Table 2). There was no significant correlation between SBS and microleakage (r=-0.045, P=0.796).

The results for the ARI scores are displayed in Table 3. The chi-square test revealed no significant difference in the distributions of ARI scores among the control and NaF-treated groups (P=0.728). In both groups, most adhesive remained on the enamel surface after debonding.

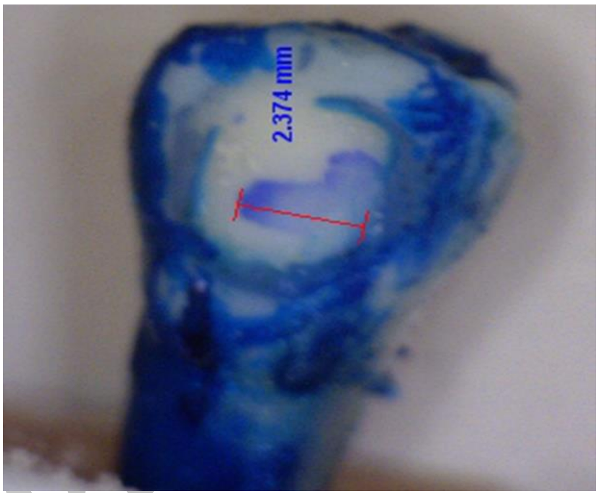

Figure 1. The occurrence of microleakage under the bracket

Table 1. Descriptive statistics including mean, standard deviation (SD) and range of the SBS values (MPa), and the results of independent-samples t-test for comparison among the groups

Group	Mean	SD	Range	*P*-value
Control	8.31	2.55	3.60-12.44	0.589
NaF	7.90	1.78	4.88-12.62	

Table 2. Descriptive statistics including mean, standard deviation (SD) and range of the microleakage values (mm) and the results of Mann–Whitney *U*-test for comparison among the groups

Group	Mean	SD	Range	*P*-value
Control	0.61	0.80	0.00-2.43	0.258
NaF	1.02	1.13	0.00-3.08	

Table 3. The distribution of ARI scores in the study groups

Group	Score 0	Score 1	Score 2	Score 3
	Number (%)	Number (%)	Number (%)	Number (%)
Control	1 (5)	7 (35)	10 (50)	2 (10)
NaF	0 (0)	9 (45)	9 (45)	2 (10)

Discussion

Caries development under and around orthodontic brackets is a great concern in patients undergoing fixed orthodontic treatment. Although enamel decalcification can be greatly reduced by maintaining good oral hygiene, it is still necessary to take advantage of supplementary products for caries prevention. The results of a systematic review revealed that the use of topical fluoride agents in addition to fluoride toothpaste appears to reduce the incidence of white spot formation in patients with fixed orthodontic appliances (17).

The mechanism of fluoride in reducing enamel demineralization is multifunctional. Fluoride increases the enamel resistance to caries and interferes with the metabolism of microorganisms (18). Reaction of fluoride with the enamel forms calcium fluoride and fluoroapatite, which in turn; they enhance the remineralization of enamel and make it more resistant to acid dissolution (12). Some authors presumed that the formation of these reaction products on the etched enamel surface may act to reduce the resin bond strength (18,19). Kim et al. (12) reported that adding an acidulated phosphate fluoride (APF) gel to the phosphoric acid etchant adversely affected the bond strength of orthodontic brackets. It has been suggested that the presence of fluoridated hydroxyapatite crystals may result in less number of chemical bonds between enamel and adhesive compared with pure hydroxyapatite crystals (20).

In the present study, application of 2% neutral sodium fluoride before acid etching did not significantly affect the SBS of metallic brackets. Therefore, fluoride therapy before the bonding procedure may be considered harmless with regard to SBS, while it potentially provides a rapid uptake of fluoride in enamel which would be helpful in prevention and remineralization of initial caries in patients undergoing fixed orthodontic treatment.

The outcome of this investigation is consistent with that of Shahabi et al. (21) who reported comparable bond strengths of orthodontic brackets in the control and NaF-treated groups. Similarly, the use of topical fluoride agents in the studies conducted by Damon et al. (10), El Bokle and Munir (14), and Kimura et al. (15) did not significantly affect the SBS of orthodontic brackets. In contrast, the application of an acidulated phosphate fluoride (APF) or a 5% sodium fluoride varnish caused a significant decrease in SBS of orthodontic brackets in the study conducted by Leodido et al. (5) which was ascribed to the deficiency in the penetration of resin into enamel surface.

In the field of restorative dentistry, microleakage is the seeping and leaking of oral fluids and bacteria along the tooth-restoration interface. From the orthodontic point of view, microleakage presents the possibility of white-spot formation beneath the brackets and may also lead to corrosion and bracket detachment (22,23). In the current study, some degree of microleakage was observed in both groups with amounts ranging from 0 to 2.43 mm in the control group and 0 to 3.08 mm in the NaF-treated group. The microleakage under orthodontic brackets was not significantly different among the two groups. In contrast, Moosavi et al. (23) reported that fluoride treatment before acid etching caused a significant decrease in microleakage under orthodontic brackets bonded to demineralized enamel, although their result cannot be compared with that obtained in sound enamel.

The findings of the present study indicated no significant relationship between bond strength and microleakage, which agreed with the results obtained by James et al. (24), along with some studies in the restorative literature (25,26). Abdelnaby and Al-Wakeel (27); however, reported a significant reverse relationship between SBS and microleakage, but with a relatively low correlation coefficient (r=-0.318).

With respect to the ARI scores, the most frequent type of failure occurred within the adhesive, with most of the adhesive remaining on the enamel surface of the specimens in both groups. Contrary to these results, Leodido et al. (5) reported that failures predominantly occurred at the enamel-resin interface in the specimens treated with fluoride solutions prior to bracket bonding.

Caution should be taken when interpreting the results of any in vitro bond strength study, particularly when predicting the clinical performance. Currently, there is no universally accepted minimum clinical bond strength. Reference publications have suggested that bond strengths of 6–10 MPa are sufficient for orthodontic bracket bonding (28, 29). Therefore it can be drawn that the values obtained in the current study were within the strength limits accepted for most procedures in clinical orthodontics.

Considering the limitations of this *in vitro* study, it may be concluded that NaF treatment prior to acid etching of sound enamel neither significantly affected bond strength nor microleakage under orthodontic brackets, and thus it can be recommended as a suitable approach to reduce the incidence of white spot lesions in orthodontically treated patients.

Acknowledgements

The authors would like to thank the vice chancellor for research of Mashhad University of Medical Sciences for the financial support of this project (grant no 900356).

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Corresponding Author:
Nadia Hasanzadeh
Dental Research Center
School of Dentistry
Mashhad University of Medical Sciences
Vakilabad Blvd, Mashhad, Iran
Tel: +98-8829501
Fax: +98-5118829500
E-mail: hassanzadehn@mums.ac.ir