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EFFECT OF WHITE SPOT LESION PRETREATMENT WITH SILVER DIAMINE FLUORIDE COMPARED TO DIODE LASER ON THE SHEAR BOND STRENGTH OF ORTHODONTIC BRACKETS. AN IN-VITRO STUDY.

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ABSTRACT

Objective: *The aim of this study is to determine the impact of silver diamine fluoride and diode laser on the shear bond strength of orthodontic brackets in-vitro.*

Materials and methods: *Fifty natural human premolars were used in this study. The sample was randomly divided into five groups (10 teeth in each group) as follows: Group 1: control group with no intervention, group 2: SDF application before enamel etching, group 3: SDF application after enamel etching, group 4: DL application before enamel etching, group 5: DL application after enamel etching. Then the bonding procedure followed. Each specimen was tested to failure in shear mode. After debonding, the adhesive remnant index (ARI) was calculated.*

Results: *The mean shear bond strength of the orthodontic brackets when DL was applied after enamel etching was significantly higher than the other intervention groups but lower than that of the control group. SDF groups and DL group applied before enamel etching had the least mean shear bond strength with no statistically significant difference among them. ARI scores for the different groups indicated no significant differences in their distribution frequencies.*

Conclusions: *SDF and DL maintained high shear bond strength to orthodontic brackets. ARI score showed no statistically significant difference in failure site between all groups.*

Keywords: Silver diamine fluoride; white spot lesion; diode laser

INTRODUCTION

The aim of orthodontic treatment is to regain both esthetics and function; yet, previous reports have shown that more than 80% of patients who look for orthodontic consultation are seeking esthetic improvement of their teeth [1]. Orthodontically induced white spot lesions (WSLs) represent a considerable challenge for achieving the planned goal of excellent esthetic result [2–4]. It is a poular clinical issue as orthodontic brackets can lower adequate oral hygiene preservation and furnish greater surface area for dental plaque attachment. This can lead to a higher risk of incipient caries on tooth surfaces not usually susceptible to carious insult [4–7]. Therefore, in patients with a high risk of WSLs progress during orthodontic intervention, extra preventive measure is needed [3,8,9]. This extra prevention is extremely critical as the prevalence of WSLs is soaring [9–11].

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Previous studies suggested that the incidence of white spot lesions around orthodontic brackets that occur during active treatment ranges between 30% and 70% of patients [4,10,12]. Recently, the application of silver diamine fluoride and diode laser showed promising results in the prevention of WSLs [13–16].

Silver diamine fluoride (SDF) is the highest concentrated fluoride product (44,800ppm) commercially at hand for caries management [17]. Chu et al[13] demonstrated that SDF can result in a 54% limitation of new caries attack. Silver is an antimicrobial component and fluoride enhance enamel remineralization. SDF interacts with calcium and phosphate ions and creates fluorohydroxyapatite [18–20]. On a parallel level, the use of diode laser (DL) seems to be an attractive fluoride replacement, since many studies reported that when laser is used alone or with fluoride, it may enhance the dental resistance to caries attack [21,22,23]. Diode laser enhances the resistance of enamel to acidic attack [14,15]. It alters enamel chemical and morphologic structure rather than ablating the tooth enamel surfaces which happen with hard-tissue lasers [24].

In order for SDF or diode laser to be applied for preventing white spot lesions, we must first show that they do not negatively affect the bond strength between the orthodontic bracket and etched enamel surface [25,26]. While SDF application showed good results in WSLs prevention, research concerning its effect on shear bond strength of orthodontic brackets is deficient [27]. Moreover, previous literature report has no sufficient data on whether or not diode laser application for WSL prevention negatively alter the bond between orthodontic attachments and etched enamel. To our knowledge, no other study tested the shear bond strength of orthodontic brackets when using diode laser as part of white spot lesion prevention protocol. Therefore, the current study aim is to determine the impact of silver diamine fluoride and diode laser on the shear bond strength of orthodontic brackets in-vitro.

MATERIAL AND METHODS

Sample Size Calculation

Sample size calculation was done in accordance with a previous study by Favero et al[18] who examined if silver diamide fluoride can affect enamel shear bond strength using thirty human teeth with ten teeth in each group. Sample size was calculated using G* power software version 3.1.3 (University of Dusseldorf, Dusseldorf, Germany) for the primary outcome. When the power was set at 80% and a significance level of 0.05, the power analysis yielded a total sample size of fifty specimens.

Sample preparation

A total of fifty natural human premolars were used in this study. They were selected free from caries, with no enamel defects or demineralization and extracted for therapeutic purposes. They were collected from the Orthodontic Department, Faculty of Dentistry, Ain Shams University.

The collected premolars were placed in 6% sodium hypochlorite solution for 24 hours to remove all soft tissues, staining and plaque. Teeth were examined under stereomicroscope (SZ-Olympus, Japan) using 10x magnification. Those with cracks, stains or lesions were eliminated from the study.

Sample Grouping

Sample was randomly divided into five groups (10 teeth in each group) as follows:

- **Group 1: No intervention (control group).**
- **Group 2: Silver diamine fluoride application before enamel etching.**
- **Group 3: Silver diamine fluoride application after enamel etching.**
- **Group 4: Diode laser application before enamel etching.**
- **Group 5: Diode laser application after enamel etching.**

Experimental steps

The enamel surface of each tooth was cleansed for 5s with a non-fluorinated pumice paste using rubber prophylactic cup in a low-speed handpiece to insure removal of all surface contamination. A circular motion was used to avoid damage to any surface of the enamel. Water rinsing for 20s was done for each specimen. Teeth were then air dried. Treatment of the buccal surface of the premolars in each group was done as follows:

Group 1: Control. Intact enamel surface was etched with 35% phosphoric acid etching gel (Ultradent Products, South Jordan, UT, USA) for 30s, followed by a water rinse for 30s and air dried gently.

Group 2: Two drops of SDF solution (Advantage Arrest^{tm}, Elevate Oral Care, West Palm Beach, Fl, USA) were dispensed into a mixing well, applied directly to the tooth surface with a micro brush for 10s as one coat. SDF was left for one minute to make sure its penetration. After 1 min, excess SDF was removed with a cotton then the buccal surface was water rinsed for 30s then air-dried for 5 seconds [28,29]. This was followed by etching procedure as described in group 1.

Group 3: After etching and drying the buccal surface as in group 1, SDF was applied following the same protocol described in group 2.

Group 4: Diode laser (Plastic Manual Zolar Dental Diode Laser) was applied to the intact enamel of the buccal surface of the premolars. The following parameters were used: 810nm wavelength, 2W output power, 40s irradiation time, 400µm tip diameter in continuous mode laser source [30]. The laser beam was directed over 1mm of the buccal surface maintaining the same distance to the teeth. Then the enamel surface was etched and dried as in group 1.

Group 5: After etching and drying the buccal surface of the premolars as done in group 1, diode laser was applied to the enamel of the buccal surface as described in group 4.

Bonding procedure:

The procedure was done according to the manufacturer instruction as follows:

A uniform thin layer of liquid primer Transbond XT (primer, 3M Unitek, CA, USA) just enough for complete coverage of the bracket base was applied to the enamel surfaces with a disposable applicator, which was then air blown to dry the primer into a thin film. Then the primer was polymerized via Blue Phase C8 LED light curing unit (Ivoclar Vivadent, USA). This unit has a light intensity of 800mW/cm^2 and wavelength range of 430-490nm. Curing was done for 10s.

Then the adhesive was applied to the mesh-back of the metal bracket. Premolar stainless-steel standard edgewise 0.022-inch slot brackets (American Orthodontics, Sheboygan, USA) were used in this study. All the brackets were then bonded to the buccal surface of the premolars using a bracket gauge (Ormco corporation, Glendora, California USA). A force gauge (Dentaurum, Turnstrabe, Ispringen, USA) was used to apply a standardized pressure force of 300grams to seat each bracket in place [31]. This pressure was to make sure that a uniform thin layer of the adhesive was present between the enamel surface and bracket base. After the bracket was bonded, excess adhesive was removed with sharp scaler (DUFLEX, Petrópolis, RJ, Brazil). Light curing was done for 20s from the mesial side and 20s from the distal side. The actual light intensity was tested each time with the light meter built into the handpiece holder of the curing unit.

Teeth preparation for SBS:

Teeth were embedded in individual self-cure acrylic resin blocks (1.5mm × 2.5 mm) up to the level of cemento-enamel junction using custom-made form made of Teflon (Fig. 1). Teflon was used so that the acrylic does not stick to it. The form is divided into compartments where each tooth is placed to make an acrylic block around it. The procedure was as follows:

Each tooth facial surface was aligned perpendicular to the base of the Teflon form using a mounting jig of stainless-steel rectangular wire (0.021 inch × 0.028 inch) passing through the bracket of each tooth. Self-cure acrylic resin was added around each root up to the level of the cemento-enamel junction till the acrylic was cured around the root. Then the Teflon form and mounting jig were removed leaving each tooth in its acrylic block. Teeth blocks were then stored in distilled water at 37ºC for 24 hours until the time of debonding [32].

Testing machine:

Each specimen was mounted in an Instron Universal Testing Machine (Com-ten industries, Florida, USA) and tested to failure in shear mode using a blunt stainless steel blade via the flattened end of a steel rod with a 30° beveled termination applied perpendicular to the resin-enamel-bracket interface in an occluso-gingival direction at a crosshead speed of 0.5 mm/min [33].

A computer connected with the Universal Testing Machine recorded the results of each test. The maximum load necessary to debond the orthodontic bracket was recorded in Newton and then converted into Mega Pascal units (MPa) as a ratio of Newton to surface area of the bracket. The average surface area of the bracket base was 11.2 mm^2 as supplied by the manufacturer.

Residual adhesive assessment

After debonding, the premolars were examined under 10× magnification using stereomicroscope (SZ-Olympus, Japan).

Images were taken with the attached camera (Olympus DP23, Japan). The images were transported to the computer to calculate the percentage of adhesive remaining on the enamel after bracket removal using RI viewer imaging software (Research instruments, UK). The software calculated the percentage of adhesive remaining on the enamel after bracket removal using the average surface area of the bracket base that was supplied by the manufacturer.

Adhesive Remnant Index (ARI) as described by Artun and Bergland[34] was used to assess the amount of adhesive left on enamel surface. This Adhesive Remnant Index has scores 0, 1, 2, 3. Zero indicates that no adhesive remained on the tooth, 1, less than 50% of adhesive remained on tooth surface, 2, more than 50% of adhesive remained on tooth surface and 3, all the adhesive remained on the tooth with the mesh pattern visible on the tooth. The ARI scores were also used as a more complex means of defining the bond failure site between the enamel, adhesive and the bracket base. It can show whether bond failure occurred at the enamel-adhesive interface or the bracket-adhesive interface.

Blinding

After debonding, teeth and brackets were examined by an investigator who was blinded to group allocation to determine the adhesive remnant index.

Method error

The intra-examiner reliability for ARI scoring was tested by the same researcher re-examining ten teeth one week after the first examination. One month later, the ARI scores were reexamined independently by another investigator. To avoid any examination bias, the investigators examined the numbered images blinded to groups. Intra- and inter-examiner kappa values were 0.90 and 0.87 respectively, thus showing very high intra- and inter-examiner agreement.

Statistical Analysis:

The data were collected, placed in tables and statistically analyzed. Statistical analysis was done using IBM SPSS Statistics for Windows, (Version 21.0). Armonk, NY: IBM Corp. Descriptive statistics (mean and standard deviation) were computed for each group. The assesment of normal distribution of the data using Kolmogorov-Smirnov and Shapiro-Wilk tests and for homogeneity of variance using Levene statistic.

The one-way analysis of variance (ANOVA) was used as a parametric test of significance between the samples. When significant differences were present, Post hoc test (Tukey HSD) was used to asses which means were significantly different from each other. The Chi-square test was used to determine significant differences in the ARI scores between the different groups.

RESULTS

The descriptive statistics for the shear bond strength (in megapascals) for all groups are presented in (table 1). The mean shear bond strength values and standard deviation for all groups are shown in (Fig. 2).

Kolmogorov-Smirnov showed that collected data are normally distributed and Levene's test indicated the homogeneity of variance.

The results of the analysis of variance (ANOVA) comparing the different groups showed the presence of statistically significant differences between them ($P<0.01$). One way ANOVA followed by Tukey's post hoc test revealed that the mean shear bond strength in group 1 (control) was significantly higher than that of the other groups (mean=37.93±6.5 MPa). The mean shear bond strength in group 5 (diode laser applied after enamel etching) was less than that in group 1 but significantly higher than that of the other groups (mean=31.80±3.2 MPa). Moreover, group 2 (SDF applied before enamel etching), group 3 (SDF applied after enamel etching) and group 4 (diode laser applied before enamel etching) had the least mean shear bond strength (mean=25.76±6.5 MPa) (mean=23.92±3.7 MPa) (mean=24.92±4.6 MPa) respectively with no statistically significant difference among them.

The adhesive remnant index (ARI) scores for all groups are presented in (table 2). The ARI was used to calculate the amount of residual adhesive remaining on each tooth. The amount of residual adhesive remaining on the teeth varied according to the enamel surface treatment. The ARI was also used to determine the bond failure location between the different groups.

A Chi-square test comparing the ARI scores for the different groups indicated no statistically significant differences in their distribution frequencies ($P=0.87$). Group 1, group 4 and group 5 had high frequency of ARI=0. Group 1, group 2 and group 4 had high frequency of ARI=1. This indicates that failure occurred at the enamel-adhesive interface. Group 3 had greater frequency of ARI=2 which was not statistically significant from the other subgroups. This indicates that failure occurred at the bracket-adhesive interface.

DISCUSSION

Since the evolution of bonding approach, significant research has been done to enhance the bond between orthodontic brackets and dental enamel while reducing enamel loss from WSLs and preserving a clinically acceptable bond strength [25,35–41].

Fluoride is the principle component that enhances the strength of the enamel structure and can prevent orthodontically induced WSLs [42]. Also, the use of diode lasers may improve the tooth's resistance to dental caries [21,22].

SDF is the most concentrated fluoride solution commercially present for caries prevention [17]. It was found in Japan since 1970 and approved by the Food and Drug Administration in 2014 for the dental market. Silver diamine fluoride [Ag (NH3)2F] is a colourless alkaline solution consisting of 25% silver, 5% fluoride, 8% amine and 62% water [17]. Silver is an antimicrobial agent and fluoride encourage remineralization. SDF reacts with calcium and phosphate ions and produces fluorohydroxyapatite [18–20].

Diode lasers create photochemical effects and cause minor thermal changes that induce decomposition of the enamel organic matter that have an important part in inhibiting ionic diffusion across the surface, and thus intercept enamel demineralization [22]. To our knowledge, no study investigated the orthodontic bracket shear bond strength after diode laser use for white spot lesion prevention.

The choice of WSLs preventive modality should not have an adverse effect on the SBS of the orthodontic brackets [25,26]. Ideally, the orthodontic brackets should be able to withstand the orthodontic and masticatory forces without failure during the orthodontic treatment duration, this can be hard to maintain if the enamel surface is to be pretreated before brackets bonding. The acceptable needed bond strength of orthodontic brackets ranges between 5.9 and 7.8 Mpa [7]. In this in-vitro study, all of the samples yielded bond strengths above this range.

In our study, the application of WSLs preventive modality was applied before or after etching of the enamel. To prevent white spot lesions, it was proposed that the preventive protocol should be applied at the beginning of the therapy before or following acid etching of the enamel but prior to bonding. It was suggested that etched enamel surface undergo increased absorption of applied materials [43].

The results of the SBS of the control group was significantly higher than that of the other groups (mean=37.93±6.5 MPa). The shear bond strength of the SDF groups, applied before enamel etching (mean=25.76±6.5 MPa) or after enamel etching (mean=23.92±3.7 MPa) were significantly lower than the control group, with no significant difference between both groups. Application of SDF before or after etching lowered the shear bond strength of orthodontic brackets, yet it was still above the minimum acceptable clinical range. These results are similar to those of Markham et al[44] and in contrast to those of Camacho et al[43] and Favaro et al[45] who showed that SDF did not significantly affect shear bond strength. When diode laser was applied to the enamel surface before etching (group 4) it showed a comparable shear bond strength to that of SDF groups (mean=24.92±4.6 MPa). However, when diode laser was applied to the enamel after etching (group 5), it showed the highest statistically significant SBS (mean=31.80±3.2 MPa) compared to the other intervention groups, yet significantly lower than that of the control group (mean=37.93±6.5 MPa). This data suggests that diode laser pretreatment may not negatively affect bond strength to the orthodontic brackets. Labunet et al[46] showed that diode laser help improve the adhesion of selfetching primers. The use of diode laser lowers the shear bond strength of orthodontic brackets, like SDF pretreatment of enamel, yet still above the minimum acceptable range.

A viable explanation of the differences in bond strength values recorded in this study and some of the other studies is the difference in the type of adhesive, type of bracket and testing conditions [47]. Also some of the former studies used thermo-cycling before the shear bond strength testing [48]. Another point that could bring in variation to a research result, is the force application during the bracket seating on enamel. Some of the previous research used free-handed administration of the brackets to the tooth [40]. This undetermined amount of pressure can allow variation in the adhesive thickness and in turn to the research results. Therefore, adjusting the pressure applied using a fixed load to the bracket can provide more consistent result [49]. In this study, a force gauge was incorporated for seating brackets with a standardized force of 300 grams as previously recommended [50].

After premolar brackets bonding and debonding, the ARI scores were calculated. All the ARI scores were found to be statistically insignificant clearly demonstrating that WSLs pretreatment did not statistically affect the failure sites at the bracket-tooth interface for all groups. However, there was a tendency for mixed failure at the adhesive interface. Group 1 (control) and group 5 (diode laser application after enamel etching) showed a tendency to enamel-adhesive failure. Also, group 4 (enamel etching followed by diode laser application) showed a tendency to enamel-adhesive failure. However, group 2 (enamel etching followed by SDF application) showed mixed failure and group 4 (SDF application followed by enamel etching) showed failure at the bracket adhesive interface. SDF appears to alter the characteristic of the bond failure. Specifically (while statistically insignificant) the ARI scores showed that more adhesive remained bonded to the enamel surface in the SDF groups. this is similar to the findings of Camacho et al[43]. This retention of composite on the enamel surface has its advantages and disadvantages. For orthodontic needs, the retention of composite on the enamel instead of the debonded bracket add up to the chair-time needed to remove any composite residue [39]. On the other hand, a bond failure at the composite-bracket interface may be preferable because it is safer as there is a less possibility for enamel fracture [51]. The ARI score is based on many considerations including the bracket base design and the adhesive type and not simply on the bond strength at the interfaces [52].

The choice between the use of SDF or diode laser for the prevention of WSLs is based on many aspects. The cost of fluoride is significantly lower than that of diode laser, and the use of fluoride application is popular within the dental community, hence does not entail any extra training or certain qualification for its use. Nevertheless, the advantage of the morphological changes produced by the laser on the enamel structure may introduce a higher acid resistance of the enamel in the long-term [16]. Fluoride preventive feature needs multiple application, as the effect duration is short. On the other hand, if the diode laser enamel surface modification is lasting, this would make it more worthy for protecting the enamel around orthodontic brackets. Therefore, laser use for WSLs prevention may be preferable although it may be more costly than topical fluoride applications. Regarding SBS, the optimal WSL prevention system would be the one that provides the highest enamel protection, while providing clinically acceptable bond strengths. In this study, both SDF and diode laser showed acceptable bond strength values, above the minimal clinical range.

CONCLUSIONS:

1. **Silver diamine fluoride and diode laser maintained high shear bond strength to orthodontic brackets.**
2. **Enamel surface without pretreatment had the highest shear bond strength to orthodontic brackets followed by diode laser application after enamel etching.**
3. **The ARI score showed no statistically significant difference in failure site between all groups.**

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FIGURES legends:

Fig. (1): Custom-made form made of Teflon and the mounting jig.

Fig. (2): Bar chart showing mean shear bond strength values (±SD) of all groups.

Table (1): Descriptive statistics and the results of Tukey test comparing the shear bond strength (in MPa).

Group	No.	Mean	Standard Deviation (SD)	Range	Tukey test*
Group 1	10	37.93	6.5	38.2-29.6	a
Group 2	10	25.76	6.5	36.3-18.6	b
Group 3	10	23.92	3.7	29.4-19.7	b
Group 4	10	24.92	4.6	27.4-17.9	b
Group 5	10	31.80	3.2	37.7-28.7	c
p<0.05					

* Groups with different letters are significantly different from each other at p<0.05

Table (2): Frequency distribution of Adhesive Remnant Index

Groups	ARI score 0	ARI score 1	ARI score 2	ARI score 3
Group 1	3	4	2	1
Group 2	2	4	3	1
Group 3	1	3	5	1
Group 4	4	4	1	1
Group 5	3	2	3	2