The Effects of Enamel Protective Agents on Shear Bond Strength After Rebonding of Stainless Steel Orthodontic Bracket (An *in Vitro* Study)

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ABSTRACT

Background: Bracket rebonding is a common problem in orthodontics which may result in many drawbacks. The aims of this study were to evaluate the effects of application of two enamel protective agents "Icon" and "ProSeal" on shear bond strength before and after rebonding of stainless steel orthodontic brackets using conventional orthodontic adhesive and to assess the site of bond failure.

Materials and methods: Fifty sound extracted human upper first premolar teeth were selected and randomly divided into two equal groups; the first time bonding and the rebonding groups (n=30). Each group was subdivided into control, Icon and ProSeal subgroups. The enamel protective agents were applied after etching (preconditioners). Shear bond strength before and after rebonding of stainless steel brackets were assessed using the Universal testing machine and the adhesive remnant index was used to find out the bond failure site using a stereomicroscope. Then the results were statistically analyzed using one-way ANOVA analysis test and T-test.

Results: There were no significant differences in the shear bond strength mean values in either group or their corresponding subgroups. Forty percentage of the bond failure in ProSeal groups occurred away from the enamel where 75% of those were at the enamel protective agents/adhesive interface.

Conclusions: The application of Icon and ProSeal did not compromise the shear bond strength and the application of the ProSeal may protect the enamel surface from trauma (cracks, chipping or detachment).

Keywords: enamel protective agents; shear bond strength; rebonding.**(J Bagh Coll Dentistry 2017; 29(1):170-176)**

INTRODUCTION

One of the greatest problems that occasionally faces the orthodontists during and at the end of the treatment with fixed braces is the appearance of white spot lesions (WSLs) and enamel demineralization which may occur due to plaque accumulation that enhanced by the fixed appliances.[(1)]

Bracket rebonding, on the other hand, is a frequently occurring problem during orthodontic treatment. [(2)]

Mechanical removal of adhesive can cause scarring and alteration of the enamel surface with the removal of the outer enamel layer which contains high minerals compared to the deeper layer. This may eventually lead to an increase in the risk of enamel demineralization. [(3)]

Different methods have been studied to prevent or reduce the occurrence of WSLs during the course of orthodontic treatment such as the use of fluoridated mouth rinse, gel and fluoride containing tooth paste. [(1)] However, studies have shown that there was a direct association between the patient compliance to oral hygiene programme and the reduction in the development of WSLs. [(4)]

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The use of preventive agents that do not depend on the patient's cooperation has been increased to control the development of WSLs. These preventive agents include topical applications of Casein phosphor-peptide-amorphous Calcium Phosphate or fluoride, [(5)] glass ionomer cement [(6)] and adhesive resin with antibacterial agents. [(7)]

During the past decade, the use of fluoridated sealant, which acts as fluoride reservoir that releases fluoride over a long period of time, was proposed. [(8)] One of these sealants was ProSeal (Reliance Orthodontics). It has been shown that ProSeal provided maximum protection against enamel demineralization and WSLs formation. Additionally ProSeal released fluoride ions in a sustainable way over a period of 17 weeks. Furthermore it can withstand the tooth brush abrasion and acid challenge. [(9-11)]

On the other hand, the effects of low-viscosity resins infiltrant "Icon" on enamel demineralization have been increasingly studied. It has been shown that Icon infiltrant prevented enamel surface demineralization. [(12)] The Icon infiltrant could be applied after bonding of orthodontic bracket; however, there are some drawbacks which include the difficulties in application procedure in dental crowding cases. Additionally, in order to achieve its effective protective effect, multiple applications are necessary, which is a patient compliance dependent practice. [(13)]

Therefore, applying this material before bonding may exert a better effect. It was found that the low viscosity resin infiltrant provided better sealing ability when combined with the conventional bonding agent than alone.(14)

There is inconclusive information whether these agents increase or decrease the shear bond strength (SBS).Therefore the use of enamel protective agents may have a great advantageous effect during bracket rebonding situations.

The aims of the current study were to evaluate the effects of the application of enamel protective agents (EPA) on the bond strength and the adhesive failure site after rebonding of orthodontic bracket.

MATERIALS AND METHODS

Fifty samples of freshly extracted sound human upper first premolars teeth were selected after being examined with 10x magnifying lens. (15) Teeth were grossly intact with no restoration or caries; no cracks or any surface irregularities and marked structural or developmental anomalies such as enamel hypoplasia or decalcification.

Teeth were stored in a closed container at room temperature in normal saline solution (Panther, UK) containing 0.1% thymol (Sigma, Poole, Dorset, UK) to prevent dehydration and microbial growth.

Retentive cuts were made along the sides of the roots of each tooth to increase the retention inside the acrylic. (16) Teeth were then fixed onto a glass slide (Star) in a vertical position using a sticky wax at the apex of the root using a dental surveyor (Dentaurum, Paraline, Germany) so that the force is applied at a right angle to the enamel bracket interface.(17,18) Teeth were mounted in auto polymerised acrylic resin (BMS Dental, Buonarroti, Cappannoli, Italy) in a vertical position with the root embedded in the acrylic block made from a specially designed molds where the crowns of the teeth protruding outside. The powder and liquid of the auto polymerised acrylic resin were then mixed, in a ratio of 2:1 according to the manufacturer's instructions, and poured around the teeth to the level of cemento-enamel junction. (8,19) After setting has been completed, the samples were stored in a patch containing normal saline solution (Panther) with 0.1% thymol (Sigma) which is regularly changed until bonding procedure.(20)

The samples were randomly divided into two groups: the first time bonding group (G1) and the rebonding group (G2). Each group was subdivided into three subgroups: the control, Icon (DMG, Hamburg, Germany), ProSeal (Reliance Orthodontic Products, Itasca, IL, USA) and the control group which received Heliosit orthodontic adhesive (Ivoclar, Vivadent, Schaan, Liechtenstein) only without protective agents. Each subgroup consists of ten samples apart from the control of G1 which contain 30 teeth.

Stainless steel orthodontic brackets for upper first premolars (0.022 × 0.030 inch slot standard edge wise, Dentaurum, Inspringen, Germany) were used. The buccal surface of the enamel was cleaned with a rubber cup and non-fluoridated pumice for 10 seconds using a low speed headpiece (NSK, EC, Japan). (21, 22) The enamel surface was then washed for 10 seconds and dried with oil-free steam of air for another 10 seconds. (8, 23, 24) After that, an etching gel 37% phosphoric acid (Ivoclar, Vivadent, Schaan, Liechtenstein) was applied using a disposable brush on the buccal surface of the teeth for 30 seconds according to the manufacturer's instructions, and then washed with air/water spray and dried with oil-free steam of air until the buccal surface of the etched teeth appeared chalky white. (25)

In the control subgroups, the brackets were bonded to the enamel surface of the teeth by applying a thin layer of Heliosit adhesive (Ivoclar) on the middle of the middle third of the buccal surface.(25) Then, a constant load of 200 gm was applied on the bracket for 10 seconds. (26-29) The adhesive material was cured for 40 second (10 seconds curing time was set for each of the four directions; mesial, distal, occlusal and cervical) using Vivadent light cure unit with wave length range 400-500 nm and light intensity more than 500mW/cm^2. (16,30) Regarding the Icon subgroups, one coat layer of the low viscosity Icon-Dry (DMG) was applied and left to set for 180 seconds, and then light cured for 60 second. A second layer was applied, left to set for 60 seconds and then light cured for 40 seconds according to the manufacturers' instructions. 31 After that, Heliosit adhesive (Ivoclar) was applied similar to the control subgroup.

Regarding ProSeal subgroups, the ProSeal varnish (Reliance Orthodontic) was applied with a micro-brush on the etched tooth surface and light cured for 20 seconds. 32 After that, the adhesive was applied as described in the control subgroup.

The samples were then immersed in 0.1% thymol solution and stored in an incubator (Fisher scientific, USA) at 37°C for 24 hours prior to testing procedure. 8, 17, 33

Shear bond strength test was done 24 hours after bonding procedure (8, 17, 33) in a Universal testing machine (H50KT, Tinius Olsen Co., England). Each specimen was placed in the

machine base parallel to the horizontal plane. A custom made chisel-end rod was fitted inside the upper arm of the testing machine parallel to the middle third of the buccal surface of the tooth and perpendicular to the enamel bracket interface. This was done to provide a force in an occluso-gingival direction. [12, 27, 34] The crosshead speed was 0.5mm/minute [35] and the highest magnitude of the load values were recorded as the load of the bond failure. The failure load (in Newton) was divided by the base bonding area (13mm^2 in the current study) to calculate the shear bond strength in MPa (N/mm^2).

The adhesive remnant index (ARI) was assessed immediately using Stereomicroscope (Hamilton, Italy) with a magnification of 20 x.[36-39] The ARI was scored according to Artun and Bergland [40] with its modified version (ARIM) which includes scores for enamel protective agents (EPA)/ adhesive bond interface failure and enamel detachment. The scores are as followed:

Score 0 indicates no adhesive was left on the enamel surface of the tooth,
Score I indicates less than half of the adhesive was left on the tooth surface,
Score II indicates more than half of the adhesive was remain on the tooth surface,
Score III indicates all the adhesive was left on the tooth surface, with an impression of the bracket mesh,
Score IV indicates EPA /Adhesive bond failure, and Score V indicates enamel detachment.

After complete assessment, teeth from the control group (n=30) were prepared for rebonding procedure using 12-blade tungsten carbide bur (#7642, Jet carbide burs, Beavers Dental, Morrisburg, Canada) at low speed (30,000 rpm) with copious water cooling system.[42] The samples were then subdivided randomly into the three subgroups as mentioned previously using similar way of EPA /adhesive application.

Statistical analysis

Descriptive statistics, which includes the means, standard deviation, standard errors, minimum and maximum values of SBS were calculated for each subgroup in the G1 and G2 groups. Analysis of variance (ANOVA) was used to test the differences among the shear bond strength mean values of the subgroups in each group. T test was used to test the differences in the shear bond strength mean values between G1 and G2. Chi-square was used to assess the differences between the groups and within the subgroups regarding the bonding failure site (ARI).

RESULTS

Descriptive statistics of the SBS of the control, Icon and ProSeal subgroups in G1 and G2 groups are presented in figure 1.

The results obtained from the current study showed that the mean shear bond strength values of the tested materials were higher than the optimal limits suggested by Reynolds [41] which is 6-8Mpa, and thus, sufficient for clinical use. For the first time bonding group (G1), the mean SBS of the control group has the highest mean value (16.3±3.9Mpa) followed by that of the ProSeal (14.5±3.3Mpa); whereas the Icon has the lowest value (14.5±4.4Mpa). Whereas ProSeal subgroup in rebonding group (G2) exhibited the highest values (15.8±4.1Mpa) followed by that of the control and the Icon groups which showed almost similar SBS mean values (15.2±4.5Mpa,14.8±3.4Mpa respectively) (Table 1).

However, the current study showed that there was statistically non-significant ($p>0.05$) difference in SBS between G1 and G2 groups (Table 2) or the subgroups of each group (Table 3)

Table 1: Descriptive statistics of the shear bond strength (MPa) of the bonding and rebonding groups

State	Groups	N	Mean	S.D.	S.E.	Min.	Max.
Bonding group	Control	10	16.338	3.977	1.258	10.13	23.08
	Icon	10	14.507	4.483	1.418	8.08	23.33
	Proseal	10	14.580	3.318	1.049	8.08	18.46
Rebonding group	Control	10	15.238	4.516	1.428	8.45	23.59
	Icon	10	14.847	3.480	1.100	10	21.54
	Proseal	10	15.807	4.156	1.314	8.72	23.33

Table 2: Comparison of the shear bond strength in the bonding and rebonding groups.

State	ANOVA	Sum of Squares	d.f.	Mean Square	F-test	p-value
Bonding G	Between Groups	21.495	2	10.747	0.687	0.512 (NS)
	Within Groups	422.294	27	15.641		
	Total	443.789	29			
Rebonding G	Between Groups	4.661	2	2.330	0.140	0.870 (NS)
	Within Groups	447.977	27	16.592		
	Total	452.638	29			

Table 3: Comparison of the shear bond strength between the correspondence subgroups of the bonding and rebonding group.

Groups	State	Descriptive statistics				State difference (d.f.=18)		
		N	Mean	S.D.	S.E.	Mean Difference	t-test	p-value
Control	Bonding	10	16.338	3.977	1.258	1.100	0.578	0.570 (NS)
	Rebonging	10	15.238	4.516	1.428			
Icon	Bonding	10	14.507	4.483	1.418	-0.340	-0.189	0.852 (NS)
	Rebonging	10	14.847	3.480	1.100			
ProSeal	Bonding	10	14.580	3.318	1.049	-1.227	-0.730	0.475 (NS)
	Rebonding	10	15.807	4.156	1.314			

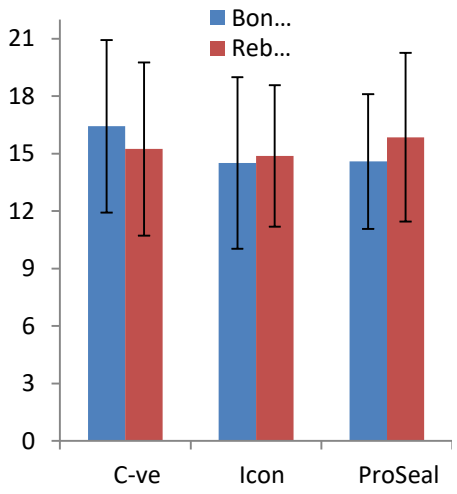

Figure 1: Shear bond strength of the bonding and rebonding groups. The error bars represent the standard deviation.

Regarding the adhesive remnant index (ARI), the predominant failure site of the control and Icon groups were near the enamel surface (scores 0 and I) regardless of the bonding sequence. On the other hand, the ProSeal groups showed that 40% of the samples exhibited a failure sites away from the enamel i.e. scores II and IV. About 75% of those were between the EPA and the adhesive. However, the differences were statistically non-significant ($p>0.05$) between G1 and G2 groups and their subgroups (Figures 2 and 3).

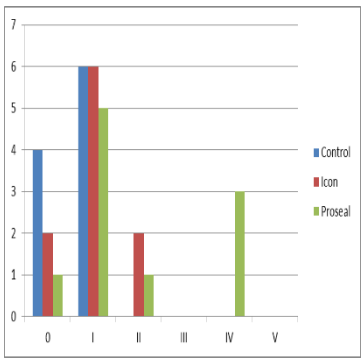

Figure 2: Bond failure site of the bonding group.

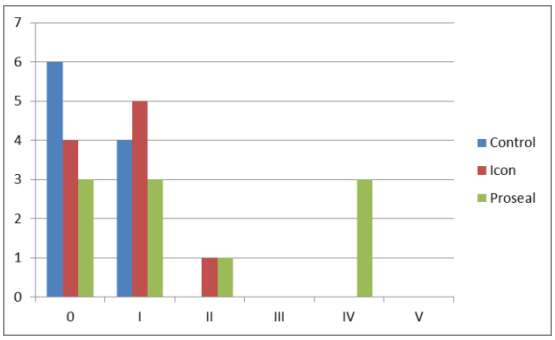

Figure 3: Bond failure sites of the rebonding group

DISCUSSION

During the course of orthodontic treatment with fixed braces, enamel decalcification, caries and gingivitis could occur in 2-96% of the patients depending on the complexity of the complications.[43] Although some demineralized enamel resolved after the removal of the appliance i.e. fixed braces, most remained causing white spot lesions (WSLs) which undermine the treatment outcomes after the treatment has completed.[44] Furthermore, enamel demineralization could occur when the high mineral layer of enamel is lost during bracket rebonding.[3]

Different methods have been proposed to reduce enamel demineralization during orthodontic treatment. [1, 7] The use of enamel protective agents and sealants are one of those measures. To the best of our knowledge, the use of Icon as a preconditioner to orthodontic adhesives during rebonding situations has not been investigated with regard to shear bond strength.

Data obtained from the current study showed that, in the bonding group, the control subgroup showed the highest SBS mean value compared to Icon and ProSeal subgroups; however, the difference was not significant.

Similarly, in rebonding group, the results showed a non-significant difference among the groups and the correspondent subgroups although ProSeal samples showed the highest SBS values.

It has been shown that the surface irregularities created during adhesive removal may cause increase in the physical area and provide microscopic holes. [45] This may result in multiple dead spaces that entrap oxygen especially in the deeper pits. It has been suggested that Oxygen may has a plasticizer effect and result in a decline in the physical properties of the polymer. Furthermore, oxygen is known to interfere with the polymerization reaction and, results in an incomplete polymerization of the adhesive [46]; this has an adverse effect on the adhesion characteristics and, eventually, results in a reduction in the mechanical properties of the resin. This is especially true in the control group where the adhesive applied without preconditioners.

However, when Icon infiltrant and ProSeal applied, the SBS values were enhanced. The low viscosity of Icon resin infiltrant together with the hydrophilic property of Icon encourages a rapid capillary penetration into the pores and irregularities [47], provides a diffusion barrier within the enamel surface created by the rebonding procedure, filled the dead spaces and tags with the microscopic holes created by the adhesive removal procedure [48] and increases the SBS. On the other hand, it has been claimed that ProSeal showed high degree of polymerization [49] which, together with the increase in surface area and the formation of grooves and facets that alter the surface free energy and surface adhesion characteristics, enhance the adhesion.[50]

Regarding the ARI scores, there were not marked effect of the application of the ProSeal and Icon on the site of bond failure in either group. However, in ProSeal groups, 40% of the failure sites were away from the enamel surface where 75% of those were at the EPA/adhesive interface. This has the advantage of preventing enamel trauma during debonding procedure

As conclusion the application of Icon or ProSeal during rebonding procedure did not compromise the SBS of the adhesive and may provide better protection to the enamel surface.

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الخلاصه

الخلفية: احدى المشاكل الشائعه التي تواجه اخصائي تقويم الاسنان هي تكون البقع البيضاء حول حاصراتتقويم الاسنان الثابت اثناء وبعد المعالجه التقويميه.انفصال الحاصرات التقويميه هي المشكله الاخرى التي كثيرا ماتحدث خلال فترة المعالجه التقويميه والتي تستوجب اعادة تثبيت الحاصرة التقويميه. خلال اجراءات عملية اعادة تثبيت الحاصره كميات كبيره من مينا الاسنان ممكن ان تفقد بسبب الازاله الميكانيكيه للماده اللاصقه مما يؤدي الى خشونة سطح مينا السن و الذي يساعد على تجمع البكتريا.

الهدف من هذه الدراسة هو تقييم تأثير واقيات مينا الاسنان (Icon),(ProSeal) على القوة القاصة لحاصرات التقويم المعدنية بعد عملية اعادة اللصق باستخدام لاصقة التقويم التقليدية (Heliosit)

الطرق والمواد: تم جمع خمسين من الضواحك العلوية الاولى من الاسنان البشرية وتوزيعها عشوائيا الى مجموعتين متساويتين (العدد=30) لاجراء اختبار القص قبل وبعد اعادة تثبيت الحاصرات. قسمت كل مجموعة عشوائيا الى ثلاث مجاميع فرعيه (العدد=10) وهي فرع السيطرة السلبية (والتي استخدمت فيه الماده اللاصقه فقط), فرع واقي المينا ProSeal و فرع واقي المينا Icon

تم فك ارتباط الحاصرات التقويمية للمجموعة الاولى (مجموعة الربط) باستخدام الة الفحص ال Tinius Olsen لقياس القوة القاصه للارتباط وذلك بعد مرور 24 ساعة على عملية الربط. بعد فك الارتباط تم تحضير العينات لعملية اعادة الربط وذلك بازالة اللاصق المتبقي باستخدام محفر التجهيز من نوع tungesten-carbideباستخدام سرعة منخفضة (30000 دورة بالدقيقة)مع نظام التبريد بالماء. بعد عملية اعادة الربط تم اختبار فك الارتباط باستخدام نفس الماكنة وذلك لقياس القوة القاصة للارتباط للمجموعة الثانية (مجموعة اعادة الربط). بعد فك الارتباط تم فحص كل من قاعدة الحاصر وسطح السن المناظر باستخدام مجهر مجسم دقيق وتم تسجيل مشعر الالتصاق المتبقي.

النتائج: اظهرت النتائج انه ليس هنالك فرق معنوي في القوة القاصة لفك الارتباط بين كل من السيطرة السلبية,Iconو ProSeal في كلا المجموعتين بالرغم من ان مجموعة الProSealبعد اعادة الربط اظهرت زيادة(غير معنوية) قليلة في القوة القاصة للارتباط. تم تحديد مواقع الانفصال بعد عملية الربط واعادة الربط. بعد عملية الربط وجد انه الانفصال كان بشكل سائد بين مينا السن والمادة اللاصقة في المجاميع الفرعية الثلاث. بينما بعد عملية اعادة الربط كان الانفصال بشكل سائد على مينا السن. في مجموعة المادة الواقية ال ProSeal كان الانفصال بنسبة 30% بين المادة الواقية والمادة اللاصقة.

الاستنتاج: وضع المواد الواقية لمينا السن الProSeal والIcon لاتوثر على القوة القاصة للارتباط بالاضافة الى انه ال ProSeal ممكن ان تحمي المينا من الاصابة بعد فك الارتباط