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The Influence of Resin Infiltration System on Sound Enamel Microhardness and Shear-Bond Strength of Orthodontic Bands: An *In-Vitro* Study

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ABSTRACT

To test the possibility that ICON bond infilterant can prevent demineralization of healthy enamel and preserve the surface hardness under orthodontic bands cemented with glassionomer (GIC) without affecting the shear bond strength of the bands. Twenty freshly extracted human premolars divided into two groups, in the control group sectioned band materials were bonded to the tooth surface using GIC,in the experimental group bonding with GIC were done following surface treatment with ICON. Both groups were subjected to pH cycling for 21 days. Microhardness was measured before and after treatment of the enamel surface. Shear Bond Strength was measured after the pH cycling. Application of ICON as pretreatment resulted in significantly lower bond strength as compared with control group. As for the enamel surface microhardness, the experimental group showed a significant increase in the microhardness following the pH cycling where the control group showed no significant difference. Within the limitation of this study, it was found that the resin infilterant ICON was able to prevent demineralization of the enamel surface under the glassionomer cement with a significant increase in surface hardness over the control group. However, the shear bond strength was reduced.

Key words: Resin infiltration system; enamel microhardness; shear-bond strength; orthodontic bands.

INTRODUCTION

Enamel demineralization is a major clinical problem encountered during orthodontic treatment not only for compromising the esthetics but also because it represents the first stage of caries formation[1,4]. Fixed orthodontic appliances complicate the oral hygiene maintenance and add to the risk of enamel lesion development[5,7]. Many studies compared the incidence of enamel white-spot lesions in orthodontically treated and untreated individuals, they reported the higher incidence to be (incidences of 11.7%,6[5] 16%[6], and 25.6%[7]) in patients who received orthodontic treatment.

Orthodontic bands are considered a cause of more enamel demineralization than brackets, due to their posterior position in the mouth they are more difficult to clean, resulting in greater plaque accumulation[8,9].

The factors contributing to enamel demineralization include compromised oral hygiene, inadequate band strength, the type of the luting cement used, cement seal breakdown, physical properties, and cement solubility in oral fluids[10].

Several techniques have been tried by researchers aiming to reduce enamel demineralization during orthodontic treatment without compromising the bond strength of the orthodontic appliance. The most common methods were the use of fluoride-containing mouth rinses, gels, and tooth pastes[11-13].

Administration of topical agents containing fluoride or casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), oral hygiene maintenance, and dietary control have been suggested as mechanisms to control the formation of enamel lesions during fixed-appliance treatment[14]. However, these strategies have considerable limitations in noncompliant patients[15]. It was found that new white spot lesions developing on the maxillary front teeth during orthodontic treatment were seen in 60.9% of the patients with only standardized general measures of prophylaxis[16]. Introducing non-patient dependent preventive measures have gained popularity by limiting the problem of demineralization.

These included the use of glassionomer cement[17,18], using antibacterial agents incorporated in the adhesive resin[19,20], fluoride releasing adhesives[21,22], bioactive glass-containing adhesives[23], laser irradiation[24,25], enamel deproteinizing agents[26], and caries infiltration resins[27,28].

The caries infiltration product ICON; a new virtually painless method, was introduced in Germany in 2009. This product utilized a special resin to seal and fill demineralized enamel without causing the loss of healthy hard tissue[29]. Icon can be used for the microinvasive treatment of initial carious lesions in the vestibular and approximal regions. The vestibular version is particularly developed for orthodontic patients after removal of braces[29]. To our knowledge, only a few studies have been conducted regarding ICON, and those have shown promising results[30]. Most studies were testing the effect on the orthodontic brackets[31-33], other studies were investigating using the resin infiltrant for treatment of the incipient carious lesion and white spots development[34,35].

Orthodontic cements have been used to improve the retention between the band and the molar, however, many of these cements showed unfavorable properties, such as low bond strengths and high solubility in oral fluids that may contribute to demineralization beneath orthodontic bands [36-38].

GlassIonomer Cements (GIC) gain the adhesion from ionic molecular interactions with both enamel and dentin as well as stainless steel, which suggests being suitable as orthodontic cements[39,40].

GICs disadvantages include brittleness and susceptibility to water attack during setting resulting in a weaker bond[41,42].

In contemporary orthodontic practice, it is important to achieve both; a reliable adhesive bond between the orthodontic appliance and the tooth enamel, as well as, A lower risk of enamel lesions development. To our knowledge no one has tried the application of resin infiltrant before band cementation in order to protect the enamel surface against demineralization which may occur following the dissolution of the cement.

Therefore, this study aimed to test the possibility that ICON bond infilterant can prevent demineralization of healthy enamel and preserve the surface hardness under orthodontic bands cemented with glassionomer without affecting the shear bond strength of the bands.

MATERIALS AND METHODS

2.1 Materials

Materials used in this study were ICON – Smooth Surface (resin infiltrant, DMG, Hamburg, Germany), Glass Ionomer (3M Unitek, USA), and, Orthodontic band material (3M Unitek stainless steel bands, USA).

2.2 Methods

This in-vitro testing used 20 extracted human upper premolars. Teeth were extracted as part of orthodontic treatment and stored in a thymol solution (0.025%) until the day of measurement. Only teeth with no cracks, restorations, or developmental lesions were selected[43].

Scaling and polishing were done in order to remove any plaque, calculi or soft tissue remnants.

The teeth were embedded in self-cure acrylic resin blocks (Acrostone, Egypt), with their convex buccal surface projecting up from the acrylic surface in order to facilitate cementation and testing. This technique was developed by the authors to facilitate measuring the shear bond strength as well as the microhardness.

Grouping:

The teeth blocks were inserted into opaque, dark and sealed envelopes and numbered sequentially. This was done for the sake of allocation concealment. The envelopes were then divided into two equal groups of 10 teeth in each group, according to the randomization list generated using online computer software (Random sequence generator;

random.org). The whole randomization process was conducted by one of the researchers which didn't participate in the rest of the study procedure.

For both groups 3M Unitek stainless steel bands were sectioned and adapted to be cemented on the exposed buccal surface of teeth. Group one; [control group] the bands were cemented to the tooth surface using Glass Ionomer (Ketac^{TM}Cem, 3M ESPE, Deutschland GmbH), powder and liquid were mixed and applied following manufacturer's instructions under a constant load of 1kg. In Group two; [Testing group] etching of the enamel surface using ICON-Etch 15% HCL gel was done then the ICON infiltrant resin was applied on the whole tooth surface and cured following manufacturer's instructions, followed by bands cementation using Glass Ionomer under a constant load of 1kg.

pH cycling[44]

The teeth blocks in both groups were inserted in a 40 ml demineralizing solution for 6 hours followed by rinsing with deionized water and then immersed in a 20 ml remineralizing solution for a period of 18 hours; in a PH cycling process. The constituants of the demineralizing solution were; calcium (2 mmol/L), phosphate (2 mmol/L), and acetate (75 mmol/L) at pH=4.3. The constituents of the remineralizing solution at 37^{o}C were; calcium (1.5 mmol/L), phosphate (0.9 mmol/L), potassium chloride (150 mmol/L), and cacodylate buffer (20 mmol/L) at pH=7. This cycling procedure was repeated daily for 21 days.

Microhardness test:

Microhardness was measured before and after treatment of the enamel surface using Digital Display Vickers Micro-hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China). The magnification used was 20X and the load applied 200g for 10 seconds. The load and time were constant for all samples throughout the study. Three indentations were made in each specimen, equally positioned over a circle 1mm in diameter. The microhardness was obtained using the following equation: HV=1.854 P/d2 [45]; where HV is Vickers hardness in Kgf/mm^2, P is the load in Kgf and d is the average length of the diagonals in mm.

Shear bond strength (SBS):

Shear Bond Strength was measured after the pH cycling and before measuring the surface hardness for the second time. Specimens in acrylic blocks were mounted vertically at a universal testing machine then a stainless steel rod with a chisel edge was used to apply vertical force in occluso-gingival direction with crosshead speed of 0.5 mm/min until failure and debonding of bands. The shear strength values were then calculated according to the following equation[6]:

Shear bond strength = load at failure/surface area of bracket

Icon smooth surface	**Icon-Etch**	15% Hydrochloric acid, pyrogenic silicic acid, surface-active substances	**DMG, Hamburg, Germany 634902**
	Icon-Dry	99% ethanol	
	Icon-Infilterant	TEGDMA based resin matrix,Initiators, additives	
Bis-GMA: Bis-phenol-A-glycidylmethacrylate; TEGDMA: Triethyleneglycoldimethacrylate.			

Descriptive statistics, including mean, standard deviation, minimum and maximum values of the shear bond strength, were calculated for each of the adhesive systems tested. T test was used to compare both groups. Significance for all statistical tests was at $P \leq .05$.

RESULTS

Descriptive statistics of Band Shear bond strength measured in mega Pascal (MPa) for both groups were presented in table (1) and graphically drawn in figure (1)

It was found that for the Control group the mean ± SD values were (3.638512±1.316912 MPa) with minimum value (1.693062 MPa) and maximum value (5.078931 MPa), while for the Experimental group the mean ± SD values were (1.298483± 0.155007 MPa) with minimum value (1.037995 MPa) and maximum value (1.431599 MPa).

It was found that the Control group recorded higher shear bond strength mean value (15.28013±3.41223 MPa) than the Experimental group(11.97111± 3.13752 MPa). The difference between both groups was statistically significant as indicated by student t-test (p=0.004 <0.05) as shown in table (2).

The numerical analysis of the Surface Hardness results measured in Vickers hardness value (HV) for both groups as function of pH cycling were presented in table (3) and graphically drawn in figure (2)

At baseline it was found that Control group recorded higher Vickers hardness mean value (318.08±20.6HV) than Experimental group(257.9±22.1HV). The difference between both groups was statistically significant as indicated by un-paired t-test (p=<0.0001 >0.05).

After pH cycling it was found that Control group recorded higher Vickers hardness mean value (326±15HV) than Experimental group(281.83±12.8HV). The difference between both groups was statistically significant as indicated by un-paired t-test (p=<0.0001>0.05).

With control group it was found that pH cycled subgroup recorded higher Vickers hardness mean value (326±15 HV) than baseline subgroup(318.08±20.6 HV). The difference between both groups was statistically non-significant as indicated by paired t-test (p=0.1072 >0.05).

With Experimental group it was found that pH cycled subgroup recorded higher Vickers hardness mean value (281.83±12.8 HV) than baseline subgroup(257.9±22.1HV). The difference between both groups was statistically significant as indicated by paired t-test (p=0.0002<0.05).

Tab. (1) Descriptive statistics of band bond strength results as function of tooth surface treatment protocol

	Control	*Experimental*
Mean	***3.638512***	***1.298483***
SD	***1.316912***	***0.155007***
SEM	0.588941	0.069321
Median	3.638512	1.327359
Minimum	1.693062	1.037995
Maximum	5.078931	1.431599

Tab. (2) Comparison of bond strength results for all groups as ranked from higher to lower value

Variables	*Mean± SD*	*Mean difference*	*t-test (p value)*
Control	***3.638512±1.316912***	2.340029	0.004*
Experimental	***1.298483± 0.155007***		

** Significant (p<0.05)*

Tab. (3) Comparison of Vickers hardness results (Mean± SD) for both groups as function of pH cycling

Variables	*Baseline*	*pH cycled*	*t-test (p value)*
Control	318.08±20.6	326±15	0.1072 ns
Experimental	257.9±22.1	281.83±12.8	0.0002*
t-test (p value)	<0.0001*	<0.0001*	

** significant (p<0.05)*

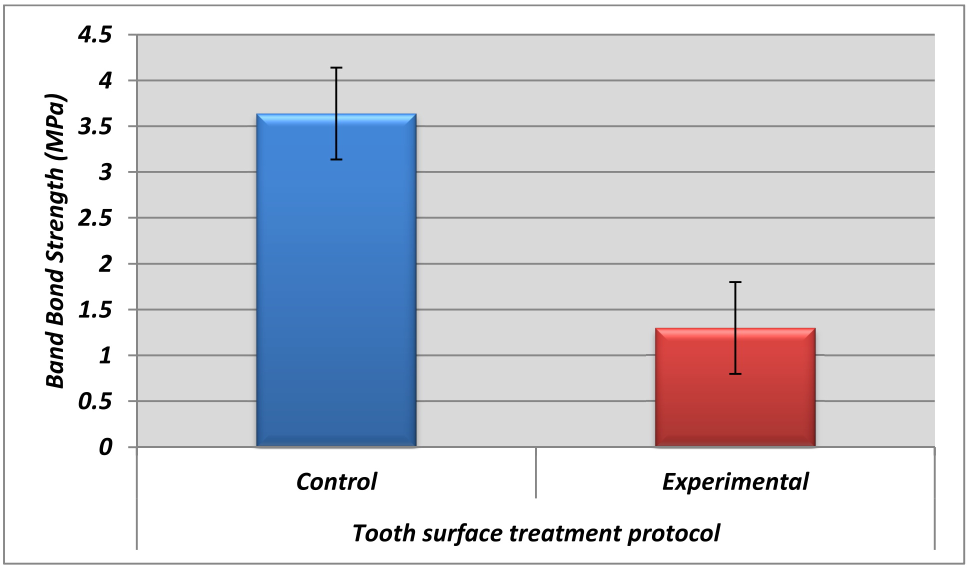

Fig. (1)**A column chart of band bond strength mean values as function of tooth surface treatment protocol**

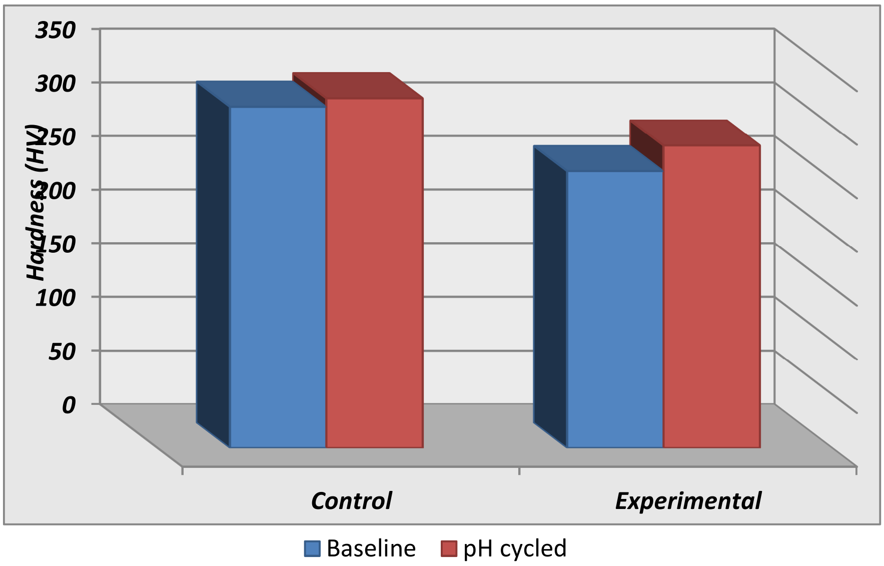

Fig. (2) **A column chart of Vickers hardness mean values for both groups as function of pH cycling**

DISCUSSION

In the present study experimental samples were treated with the resin infiltrating system ICON before banding with conventional adhesive, in keeping with manufacturers' recommendations.

Testing the shear peel band strength in most studies was done using mounted tooth clamped to a holding device in the lower load cell of the Instron machine. The holding device allowed the crown of each tooth to project and be directly below the loop attachment of the pressure transducer of the Instron machine. This arrangement allowed all forces to be directed parallel to the long axis of the tooth during debanding[46,47]. However, the technique in this study was modified such that the surface hardness on the same sample could be measured as well by using sectioned bands. This fact, lead us to testing the shear bond strength instead of the shear peel strength.

For standardization of the protocol, application of the sectioned bands to the samples (non-treated and pretreated with the infiltrating resin) were carried out by cementing the bands under a constant load of 1 Kg.

The daily frequency and magnitude of intraoral pH drops depend on many variables; such as the frequency of sugar intake, the percentage of sugar in food, and the properties of saliva and intraoral flora, which show great variations among individuals[48]. In this present study, cycles of demineralization and remineralization were applied repeatedly, resembling the oral environment for an estimated time period of 21 days. The pH cycling is considered as a good model for evaluating the demineralization process and that was the reason for using this technique in the current research[49,50].

A study found a significant increase in the shear bond strength of Transbond XT adhesive with phosphoric acid and Transbond XT primer when ICON was used before bonding orthodontic brackets to sound enamel[51] or even to demineralized enamel[52], other researchers, observed that using the caries infiltrant (ICON) before bonding did not significantly change the bond strength[31]. However, these studies were done with ICON under brackets. On the other hand, studies done on bands were mainly directed towards comparing different types of band adhesives[40,41,46,47].

To our knowledge no one had tested the effect of the resin infiltrant application before band cementation or for the prevention and not the treatment of demineralization. That was the reason that other studies couldn't be compared to this study.

In the current study, there was a significant reduction in the shear bond strength of bands cemented to enamel surfaces treated with the resin infiltrant ICON (1-1.4MPa). Measurement of the bond strength of GIC to enamel and dentine is complicated, but values in the range 3-10MPa were commonly reported [53]. The reduction in bond strength could be due to the disruption of the chemical bond of the Glass Ionomer to the tooth surface by interposing a layer of the resin infiltrant ICON that may have acted as a mechanical obstruction layer that prevented the formation of the ionic bonding between the carboxyl ions from the cement acid and the calcium ions from the tooth structure[41,42].

On the other hand, in all the previous studies on the resin infiltrant ICON, its effect on the shear bond strength was investigated in relation to different types of adhesive composites[31-33].

The pretreatment recorded VHN in the ICON group was significantly lower than those of the control group which was a normal variation given that the teeth were randomly assigned to the different groups and allocation concealment was used.

The infiltration technique aims to create a diffusion barrier inside the lesion, by replacing lost minerals with resin [54]. Following the pH cycling the experimental group showed a significant increase in the surface hardness compared to the control group in which the increase was not significant, which indicates that the resin infiltrated ICON group was more resistant to the demineralization than the untreated control group and it in fact, protected the enamel against dissolution. This was in agreement with Paris et al.[55], and schmidlen et al. [56], in which their samples showed a complete protection against demineralization. In addition, the material showed no surface degradation compared to Valinoti et al.[57], in which pH cycling of different types of composites resulted in their degradation.

On the other hand, the significant increase in microhardness compared to the insignificant increase in the control group was in agreement with studies of Montaser et al. [58], and Yetkiner et al. [59], where they found that the use of low-viscosity caries infiltrant ICON increased sound enamel resistance to demineralization.

The increased surface hardness of the enamel in the ICON group (from 257.9±22.1 to 281.83±12.8) could be related to the mode of action of the resin infiltrant material ICON. The low-viscosity light-cured resin material infiltrates the etched enamel surface creating a barrier on the enamel surface; this superficial layer increases the surface hardness of enamel and consequently improves the resistance to surface demineralization and white spot lesions development [58].

CONCLUSION

Within the limitation of this study, it was found that the resin infiltrant ICON was able to prevent demineralization of the enamel surface under the glass ionomer cement with a significant increase in surface hardness over the control group. However, the shear bond strength was reduced.

Recommendations

Further studies need to be conducted to investigate the application of ICON before band cementation with different types of band adhesives other than glassionomer cements.

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