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Effects of different adhesion promoters and deproteinizing agents on the shear bond strength of orthodontic brackets: An *in vitro* study

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Abstract:

OBJECTIVE: To evaluate the effects of different adhesion promoters, namely, Enhance LC, Ortho Solo, Assure Universal Bonding Resin and deproteinizing agents such as 5.25% NaOCl, 10% papain gel on the shear bond strength of orthodontic brackets.

MATERIALS AND METHOD: The present study was approved by the Ethics Committee of Teerthanker Mahaveer Dental College and Research Centre, affiliated to Teerthanker Mahaveer University, Moradabad, India. Around 150 extracted sound human upper bicuspids were taken and divided into six groups. Group 1 control (37% H_3PO_4), Group 2 (37% H_3PO_4 + Ortho Solo), Group 3 (37% H_3PO_4 + Assure Universal Bonding Resin), Group 4 (37% H_3PO_4 + Enhance LC), Group 5 (5.25% NaOCl + 37% H_3PO_4), and Group 6 (10% papain gel + 37% H_3PO_4). In all the groups ($n = 150$) orthodontic metal brackets were bonded with Transbond™ XT and all the samples were subjected for evaluation of shear bond strength using Instron universal testing machine at a cross speed of 0.5 mm/min. The bracket failure mode was examined using Adhesive Remnant Index (ARI). The Kruskal-Wallis test and the Mann-Whitney test were used to compare the shear bond strength. The Chi-square test was used to determine significant differences in the ARI scores among the groups. The significance for all statistical tests was $P < 0.05$.

RESULTS: Mean values of shear bond strength showed statistically significant differences between the evaluated groups ($P < 0.005$). The lowest and highest shear bond strength was attributed to Group 1 (control) and Group 2 (Ortho Solo), respectively. No statistically significant difference was noted for the mean ARI scores between control, adhesion promoters, and deproteinized group ($P < 0.05$).

CONCLUSION: It was concluded that adhesion promoters and deproteinizing agents can be used to enhance the shear bond strength of orthodontic brackets. Among all the groups Ortho Solo showed the highest bond strength when used with Transbond™ XT.

Keywords:

Adhesion promoters, Adhesive Remnant Index, brackets, deproteinization, shear bond strength

Introduction

In the past few years, great technological advances have brought numerous advantages in the field of dentistry and particularly to orthodontics. New materials and techniques help in simplifying the clinical procedures. For decades, orthodontists have approached successful, reliable orthodontic bonding in offices around the world replacing traditional bonding.[1]

Introduction of enamel etching technique by Buonocore[2] in 1955 opened new vistas in adhesive dentistry which included direct bonding of orthodontic attachment.

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Deproteinization is the removal of organic materials from the enamel surface prior to acid etching. The idea of enamel deproteinization with sodium hypochlorite (NaOCl) was first put forward by Venezie *et al*.[3] in improving the bonding efficacy to hypocalcified amelogenesis imperfect enamel. NaOCl is frequently used as a disinfectant or a bleaching agent. In addition, it is widely used in dental practices as an irrigant of root canal treatment in endodontics. Deproteinization of enamel with 5.25% NaOCl prior to bonding the orthodontic bracket was first proposed by Justus *et al*. in 2010.[4]

Recently Pithon *et al*.[5] explained that, using 10% papain gel as a protein removal agent prior to enamel etching causes elimination of chemically organic substances and increased in the bond strength.

The term "adhesion promoter" was initially used to describe a surface-active comonomer which attempts to create chemical adhesion of plastic to the tooth structure.[6] One of the first molecules of this kind was NPG-GMA and some of the first dentin adhesives were created utilizing this molecule (Bowen,[7] 1965); however, early commercial applications of products based on NPG-GMA had yielded poor clinical results (Swift,[8] 1995).

One of the adhesion boosters is Enhance LC (Reliance, Itasca, Illinois, USA) which can improve the bond strength to a variety of surfaces including alloy, porcelain, irregular enamel surfaces as well as normal enamel. It consists of hydroxyethyl methacrylate (HEMA), tetrahydrofurfuryl, cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional, one hydrophobic, and another hydrophilic group.[9]

Recently, a product called Assure R Universal Bonding Resin (Reliance Orthodontic Products, Inc., Itasca, III) has been introduced to the orthodontic community. The manufacturer mentions that Assure R Universal Bonding Resin has the adhesion promotion capacity of Enhance LC, which improves bond strength to a variety of surfaces and, in addition, eliminates the need for the bonding agent.[10]

Ortho Solo is a universal sealant (Ormco, Orange, CA, USA) that can replace the unfilled resin used in light-cured composite adhesive systems. The main constituent of Ortho Solo is BIS-GMA, a high-molecular-weight resin that acts as a base for most of the composite resin systems and also has a methacrylated phosphoric acid ester.[11]

Few studies in orthodontic fields have been published on this subject but none of them have compared the effects of different adhesion promoters and deproteinizing agents on the SBS of orthodontic brackets. Hence, the present *in-vitro* study was undertaken to evaluate the effects of different adhesion promoters and deproteinizing agents on the shear bond strength of orthodontic brackets.

Materials and Method

Around 150 freshly extracted noncarious human maxillary premolars were stored in distilled water. Before testing, the teeth were mounted in a 4-cm long steel cylinder with an internal diameter of 3 cm, using type IV die stone.

Preparation of the samples for shear bond strength

The teeth were divided into six groups ($n = 25$), and metal maxillary premolar brackets (3M Gemini, MBT 0.022 slot) were bonded on their buccal surfaces, as per manufacturers' instructions. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste.

Group 1 (n = 25)

The surface of the enamel of premolars was etched with 37% phosphoric acid (3M ESPE Scotchbond etching gel, St Paul, MN) for 15 s, washed with water, and dehydrated with moisture-free squeezed air for 20 s followed by primer application. The orthodontic brackets were bonded using Transbond XT adhesive (3M/Unitek, Monrovia, Calif) followed by photopolymerization (LED, Woodpecker) for 40 s (10 s on each side).

Group 2 (n = 25)

One coat of Ortho Solo was applied to the etched enamel. No drying or curing step is necessary. Immediately the orthodontic brackets were bonded with Transbond XT followed by photopolymerization as in control/Group 1. Ortho Solo itself acts as primer.

Group 3 (n = 25)

Two layers of Assure Universal Bonding Resin were applied to the etched enamel. The surface was lightly air-dried to evaporate the solvent; the orthodontic bracket was bonded immediately with Transbond XT followed by photopolymerization as in control/Group 1.

Group 4 (n = 25)

Two coats of Enhance LC were applied to the etched enamel, after application of second coat the enamel surface was completely air-dried until shiny. A thin layer of Transbond XT primer was applied directly to the Enhance LC coated layer and light-cured for 10 s. The orthodontic bracket was immediately bonded after application with Transbond XT followed by photopolymerization as in control/Group 1.

Group 5 (n = 25)

The enamel surface was deproteinized with 5.25% NaOCl for 60 s, followed by rinsing, drying, and enamel etching

with, 37% H_3PO_4 for 15 s. The orthodontic brackets were bonded after primer application using Transbond XT followed by photopolymerization as in control/Group 1.

Group 6 (n = 25)

The enamel surface was deproteinized with 10% papain gel for 60 s, followed by rinsing, drying, and enamel etching with, 37% H_3PO_4 for 15 s. The orthodontic brackets were bonded after primer application using Transbond XT followed by photopolymerization as in control/Group 1.

Samples testing

All the prepared samples were preserved in distilled water at room temperature for 24 hours and then subjected to shear bond strength testing. Each sample was subjected with shear load in a universal testing machine, (WDW-5, SERIAL NO. 20070802 Instron Machine, Taiwan), applied by a knife-edged blade at a cross-head speed of 0.5 mm/min. The applied force was directly parallel to the external surface of the tooth on top of the base of each bracket and a load of shear bond strength was recorded at the point of debonding. This force (kilonewton) was converted into MPa by the following formula.

MPa = Force (in N)/Surface area (In mm^2).

Bracket base was 10.61 mm^2 according to the company specification.

Adhesive remnant index (ARI)

The enamel surfaces of all the test samples were examined after shear bond strength estimation under a stereomicroscope at 16× magnification to determine the amount of the adhesive resin remaining on the surface and then classified according to the ARI. The ARI scores were arranged according to the criteria given by Artun and Bergland[12] from 0 to 3, with 0 indicating no composite left on the enamel; 1, less than half of the composite left; 2, more than half of the composite left; and 3 all of the composite remained on the tooth surface.

Statistical analysis

The Kolmogorov-Smirnov normality test and the Levene variance homogeneity test were applied to the bond strength data. As the data did not show a normal distribution, a significant difference was evaluated by using the Kruskal-Wallis test, finding those groups which were significantly different from the Mann-Whitney U-test for two independent samples. The Chi-square test was used to determine significant differences in the ARI scores among the groups. All statistical analysis were done on SPSS 21.0 software for Windows (SPSS, Chicago, III). The significance for all statistical tests was $P < 0.05$.

Results

The descriptive statistics (mean and SD) of shear bond strength was measured for all the groups. The highest mean SBS was recorded in Ortho Solo (22.51 ± 5.25). To find out the significant difference in the mean SBS among all Groups at a 95% confidence interval, the Kruskal-Wallis test was done. It was evident that the mean shear bond strength recorded between different groups is highly significant (<0.001) as shown in Table 1.

In Table 2 the Mann-Whitney U test for two independent samples was performed to find out among which pair of group, a significant difference exists. When Group 1 (control) was compared with adhesion promoters and deproteinizing agents statistically significant differences were found ($P < 0.05$). Similarly, when the comparison was done between Group 2 (Ortho Solo) and Group 3 (Assure Universal Resin), Group 5 (5.25% NaOCl) and Group 6 (10% papain gel), statistically significant differences were found ($P < 0.05$). Furthermore, when Group 4 (Enhance LC) and Group 5 (5.25% NaOCl) were compared statistically significant differences were found

Table 1: Descriptive statistics and comparative mean shear bond strength of all the groups using the Kruskal-Wallis test

Group	*n*	Min.	Max.	Mean	SD	*F*	*P*
Control							
37% H3PO4	25	7.66	28.08	13.23	4.73	8.308	<0.001*
Adhesion Promoters							
Ortho Solo	25	12.06	30.53	22.51	5.25		
Assure Universal	25	8.29	29.78	17.82	5.52		
Enhance LC	25	10.36	34.11	20.20	6.36		
Deproteinizing agents							
5.25% NaOCl	25	8.1	27.14	16.33	5.79		
10% Papain Gel	25	8.54	30.91	18.58	6.25		

Table 2: Pairwise comparison of the mean shear bond strength using the Mann-Whitney U test

Group	Group	Mean difference	*P*
Control Group	Enhance LC	-6.97	<0.001*
Control Group	Assure Universal	-4.58	0.03*
Control Group	Ortho Solo	-9.28	<0.001*
Control Group	5.25% NaOCl	-3.10	0.034*
Control Group	10% Papain Gel	-5.35	0.001*
Enhance LC	Assure Universal	2.39	0.190
Enhance LC	Ortho Solo	-2.30	0.174
Enhance LC	5.25% NaOCl	3.87	0.028*
Enhance LC	10% Papain Gel	1.62	0.382
Assure Universal	Ortho Solo	-4.69	0.006*
Assure Universal	5.25% NaOCl	1.49	0.341
Assure Universal	10% Papain Gel	-0.76	0.749
Ortho Solo	5.25% NaOCl	6.18	<0.001*
Ortho Solo	10% Papain Gel	3.93	0.023*
5.25% NaOCl	10% Papain Gel	-2.25	0.197

Mann Whitney U test, *Significant Difference

($P < 0.05$). No statistically significant difference was seen in the mean shear bond strength in rest of the groups.

ARI showed a similar pattern between the six groups. The distribution of the ARI score was compared between control group, adhesion promoters and deproteinizing agents in Table 3 using the Chi-square test. There was no significant difference in the distribution of ARI score between control group, adhesion promoters, and deproteinizing agents. ARI comparison between the groups was done by using the Kruskal-Wallis test which showed no statistically significant difference ($P = 0.176$) in the mean score among all groups at 95% confidence interval.

Discussion

The benefits of successful orthodontic treatment are well known today. While orthodontic bonding is generally successful, orthodontic bond failure occurs at 4.7–6.0% (O'Brien *et al*. 1989)[13] for a variety of reasons such as poor operator technique, moisture contamination, and excessive masticatory forces. For effective orthodontic bonding, SBS values between 5.9 MPa and 7.8 MPa are suggested to be sufficient. Noncompliant patients, fluoresced and hypocalcified teeth, debonded and recycled brackets also require additional bond strength. To achieve good bond strength, proper enamel conditioning is a must. Buonocore,[2] was the first to demonstrate that acrylic resin adhesion was more when H_3PO_4 of 85% concentration was used on the tooth. Since then phosphoric acid has been in routine use for etching the enamel to receive the adhesive resin.

Our results showed that Group 2 (Ortho Solo) produced the highest mean SBS and was statistically higher from the rest of the groups.

Table 3: Frequency distribution of the ARI of all the groups using Chi-square test

	ARI Score				Total
Groups	0	1	2	3	
Control Group	3	9	8	5	25
	12.0%	36.0%	32.0%	20.0%	100.0%
Enhance LC	0	5	9	11	25
	0.0%	20.0%	36.0%	44.0%	100.0%
Assure universal resin	3	4	11	7	25
	12.0%	16.0%	44.0%	28.0%	100.0%
Ortho Solo	1	5	9	10	25
	4.0%	20.0%	36.0%	40.0%	100.0%
5.25% NaOCl	3	6	9	7	25
	12.0%	24.0%	36.0%	28.0%	100.0%
10% Papain gel	2	4	12	7	25
	8.0%	16.0%	48.0%	28.0%	100.0%
Total	12	33	58	47	150
	8.0%	22.0%	38.7%	31.3%	100.0%
	11.524	0.715			

Chi-square value- 11.524, *P*-0.715

The findings of the present study were also supported by Vicente *et al*.[14] who evaluated the effect of the adhesion boosters Enhance LC and Ortho Solo on the SBS of the brackets cemented with a light-cured orthodontic adhesive system. The results showed that Ortho Solo significantly increased the bond strength when used with Transbond-XT.

Vicente *et al*.[15] have done a study in which they determined the SBS of the orthodontic brackets using adhesion promoter (Ortho Solo) which showed that application of Ortho Solo significantly increased the SBS.

Vijayakumar *et al*.[16] evaluated the SBS of new brackets using Enhance LC and Ortho Solo adhesion promoters. The results showed that Ortho Solo increased the bond strength of new brackets significantly.

Group 4 (Enhance LC) showed the second-highest SBS which was statistically significant from rest of the groups.

The findings of the present study were also supported by Adanir *et al*.[17] who evaluated the effects of Enhance LC on the SBS of orthodontic brackets. Results showed that Enhance LC significantly increase the SBS.

A study was done by Egan *et al*.[18] contradictory to these findings wherein they used human premolars to evaluate the efficacy of the Enhance LC Adhesion Booster when used together with a conditioner that contained methyl methacrylate for direct bracket bonding. They concluded that the use of these products did not increase the bond strength.

A study was done by Chung *et al*.[19] which also contradicts these findings wherein they evaluated the effects of Enhance LC on the SBS of new brackets. Results showed that Enhance LC failed to improve the SBS of the new brackets.

In the present study, the deproteinizing group 10% papain gel showed better bond strength which is in agreement with the findings of Pithon *et al*.[5] Thus it can be concluded that papain gel is an efficient alternative for deproteinization of the tooth enamel surface before bonding orthodontic brackets.

In the present study, an ARI score of all the groups shows a statistically no significant difference.

In the control group, most test specimens had scores of one and two, which indicated that little adhesive material was left on the enamel after bracket debonding. In the experimental group, most test specimens had a score of two and three. Therefore, there was more adhesive on the enamel when adhesion boosters and deproteinizing agents were used, particularly when

Ortho Solo and Enhance LC were applied. This may indicate that there was a bond strength increase at the enamel-adhesive interface, which made it stronger than the adhesive-bracket interface.

Clinically, Ortho Solo and Enhance are better adhesion promoters with higher adhesive remnant left on tooth surface after debonding of orthodontic bracket. The finding was supported by Vicente *et al*.[14] who found a statistically significant difference for ARI scores between the control group and Ortho Solo. The reported increase in bonding of Transbond XT to the enamel surface was due to the fact that cohesive fractures occurred between composite and bracket interface. i.e. the material remains bonded to the enamel surface and consequently prevents the enamel from eventual trauma.

The finding was also supported by a study conducted by Adanir[17] *et al.* and Kanashiro[10] *et al.* who found a statistically significant difference for ARI scores between the control group and adhesion boosters.

In deproteinizing agents ARI score reported was two and three in 10% Papain gel as compared to other groups. The finding was supported by Pithon *et al*.[5] who found a statistically significant difference for ARI scores between the control group and papain gel used in different concentrations. The reported increase in bonding of Resin modified glass ionomer cement to the enamel surface was due to the fact that cohesive fractures occurred between composite and bracket interface.

Conclusion

The conclusions drawn from the present study were as follows

1. Among all adhesion promoters Ortho Solo shows the highest bond strength while among all deproteinizing agents, 10% of papain gel shows the highest bond strength
2. All the adhesion promoters and deproteinizing agents used in this study provide a significant increase in shear bond strength with Ortho Solo, Enhance LC, and 10% papain gel having statistically significant increase in Shear bond strength as compared with the conventional method of bonding
3. An increase in the ARI scores of all the experimental groups demonstrates better adhesion of composite to the enamel surface, leading to a safer debonding after treatment as the fracture interface shifts from enamel adhesive to the adhesive bracket interface thus preventing enamel micro fractures
4. Therefore, the use of these agents gains importance where extra bond strength is required like in fluoresced, hypocalcified, and premature enamel
5. Many factors that might affect intraoral bond strength are difficult to reproduce in the laboratory. Hence, *in vitro* studies give only a hint about the optimal bonding procedure.

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Conflicts of interest

There are no conflicts of interest.

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