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International Journal of Orthodontic Rehabilitation

A Comparative Evaluation of the Shear Bond Strength of Two Different Orthodontic Bonding Agents on Artificial Crown Surfaces: An Invitro Study

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How to cite this article: *A Comparative Evaluation of the Shear Bond Strength of Two Different Orthodontic Bonding Agents on Artificial Crown Surfaces: An Invitro Study. Int J Orthod Rehabil 2023; 14 (2) 31-43. Doi: 10.56501/intjorthodrehabil.v14i2.78.*

Received : 24-03-2023 *Accepted: 02-06-2023* *Web Published:28-06-2023*

Abstract:

INTRODUCTION: Bonding of buccal tubes to the tooth is an essential procedure in orthodontic treatment. Successful orthodontic treatment requires a sufficiently high and durable bond between buccal tubes and artificial surfaces and the need for a bonding agent which can provide maximum bond strength. With the increase in the number of adult patients seeking fixed orthodontic treatment, there is a need to find a more reliable procedure to bond the artificial crown surface. This study aimed to assess and compare the shear bond strength and adhesive remnants of buccal tubes bonded to enamel, ceramic and zirconia crowns using two bonding systems.

METHODS: In this study, 60 extracted human molar teeth were randomly assigned to three groups (n=20) and divided into two subgroups (n=10). Bonding of buccal tubes to these surfaces was done using Assure Plus and Enhance L.C. A universal testing machine determined the shear bond strength of buccal tubes to these surfaces. The SBSs and ARI scores were statistically analyzed with the Kruskal-Wallis test.

RESULTS: The mean shear bond strength of buccal tubes to these surfaces bonded with Assure Plus and Enhance L.C. was highest for enamel, followed by zirconia surfaces, respectively. Nonparametric Kruskal-Wallis test found significant differences regarding the SBS and ARI.

CONCLUSION: Bonding of buccal tubes to these three surfaces with Assure and Enhance L.C. provided adequate bond strength. Thus, it may bond orthodontic buccal tubes to artificial crown surfaces in the clinical setting.

Key words: Zirconia, Ceramic, Assure plus, Enhance LC, shear bond strength.

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INTRODUCTION

With a rise in the number of adult patients seeking orthodontic treatment, orthodontists are frequently faced with the dilemma of bonding brackets/tubes onto the teeth restored with porcelain crowns, bridges, veneers or laminates, amalgam, or composite restorations.[1]

Bonding of molar tubes is essential to maintain anchorage and proper teeth sliding. Therefore, the bonding systems have been simplified and improved to increase molar tubes' long-term strength, reliability, and durability. Conventionally two main strategies are used to create durable enamel surface bonding are, firstly use of a thin intermediate layer of resin (also called primer or bonding agent) to penetrate the etched enamel surface, and secondly, self- etching systems or acidic primers to increase the bond strength between the tooth andcomposite resin.[2-3]

One of the most commonly used primer in orthodontics is Transbond XT (3M Unitek, Monrovia, California). It is a hybrid resin of Bis-GMA and TEGDMA in a proportion of 1:1, with 82% of silica particles of 3µ. Previous studies show Transbond XT had an acceptable bond strength of 9 MPa to 14 MPa. However, its bond strength on zirconia surfaceis not adequate (1.2-2 MPa).[4]

Recently Assure Plus (Reliance Orthodontic Products) bonding resin composed of BisGMA (10-30%) and ethanol (50-75%) which promotes infiltration of hydrophobic dimethacrylate resins into the interfibrillar spaces and dentinal tubules to improve stability of resin-dentin interfaces.[5] Current studies claimed to provide adequate bond strength of 6.2-7.5 MPa to normal, hypocalcified, and fluoresced enamel and higher bond strength of 12-17.2 MPa to amalgam, gold, stainless steel, porcelain, glazed zirconia, composite restorations, interim restorations, and acrylic pontics.[6] Unlike the self-etching primers this primer does not require additional silanization, thereby reducing the chair side time.[1]

Most of the studies evaluated the bond strengths of these materials, ASSURE PLUS and ENHANCE LC, on normal tooth enamel. But very limited literature is available on the bond strengths of prosthetic teeth, which is the need for fixed orthodontic treatment nowadays. So, this study primarily assessed bond strengths of these materials to bond molar tubes on both enamel and artificial tooth surfaces to determine which material is better for orthodontic purpose because assure plus is universal bonding agent and Enhance LC is better adhesion booster for promoting bond strength.

AIM:

The purpose of this study is to assess and compare the Shear bond strengths of molar tubes bonded to Natural and artificial tooth surfaces with two orthodontic primers.

OBJECTIVES:

To evaluate and compare shear bond strengths of Assure plus and Enhance LC on enamel, ceramic and zirconia crowns using UTM.

To compare and assess adhesive remnant scores of Assure plus and Enhance LC on ceramic and zirconia crowns using stereomicroscope.

NULL HYPOTHESIS

There will be no significant difference in the molar tube bond strengths between Assure plus & Enhance LC primers on ceramic and zirconia crowns bonded on extracted molar teeth.

MATERIAL AND METHODOLOGY:

SAMPLE SIZE

Sixty freshly extracted molar teeth were collected over 6 months. Sample size was calculated using G Power 3.1 software. At a level of significance set at 5%, power of the study is 80% and for an expected effect size difference of 0.413. Thus 20 samples per group were required to perform study with following Inclusion & Exclusion criteria.

INCLUSION CRITERIA:

First permanent molars extracted due to severely compromised periodontium, Non-carious teeth, Molars with intact buccal and proximal surfaces.

EXCLUSION CRITERIA: Molars damaged due to caries or trauma, compromised enamel, broken crowns, chemically and endodontically treated teeth.

JIG PREPARATION:

All the collected molars were cleaned to remove blood, tissue debris and preserved at 4 °C in 0.1% thymol solution to prevent bacterial contamination and dehydration till the bonding procedures. The teeth were then mounted on self-cured acrylic blocks such that the roots were embedded into the acrylic completely up to the cemento-enamel junction and buccal surface of the crown perpendicular to the base of the block.

TOOTH PREPARATION.

Based on the crowns to be received, they were divided into three groups of 20 each G-I (enamel), G-II (zirconia), and G-III (ceramic PFM). Tooth preparation was done by placing depth cuts of 1.5-mm to 2-mm and interproximal slices with a 330 bur. The axial walls were reduced using a tapered 0.7-mm-diameter diamond. For, porcelain fused metal crowns a minimal taper 22-30 to achieve a 1-mm chamfer margin but zirconia preparation had a taper of 15° with shallow circumferential chamfer preparation of 0.5 mm. All the finished margins were kept supragingival and impressions were made and sent to laboratory for crown to be prepared. After receiving Ceramic (PFM)and Zirconia crowns it is cemented to prepared tooth surface with luting GIC (GC corporation).[7-8]

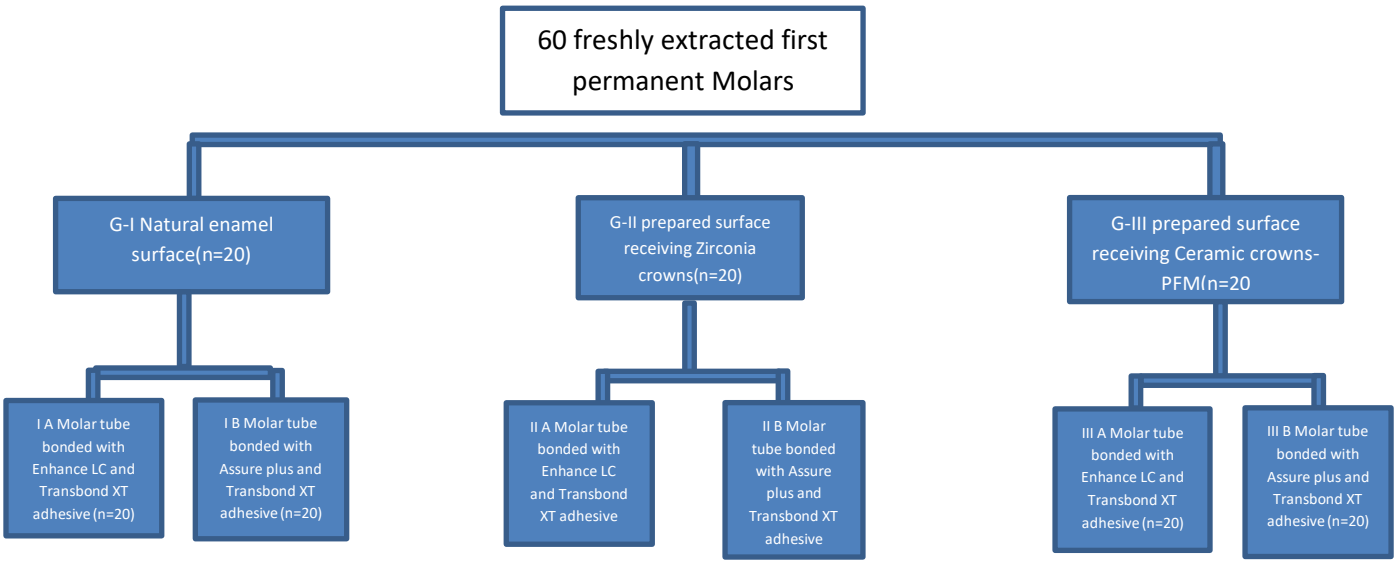

Fig I. Assure plus- Reliance orthodontics

Fig 2. Enhance LC- Reliance orthodontics

In group I, the enamel surface was etched with 37% phosphoric acid for approximately 30 seconds washed and dried till a frosty ice appearance was seen.[6] Whereas in Group II and III 9.6% hydrofluoric acid (HF)(Ultradent) was used for etching the ceramic and zirconia surface for approximately 2 minutes.[9] Study by Purmal et al showed that micro mechanical alteration of the surface of the porcelain caused irreversible damage and compromised the integrity of crown or bridge.[10]

Based on the primer used these are further categorized into subgroups A (Enhance LC), B (Assure plus).

In all three groups the buccal surface was coated with Assure plus primer (Fig 1) with an applicator tip and light-cured for 3-5 and 10 seconds.

Fig 3: Universal testing machine- INSTRON

Fig 4: Stereomicroscope- Olympus

A molar tube was bonded to the buccal surface of all the groups at center point with Transbond XT light cure adhesive paste, and excess resin is removed with an explorer before it is polymerized. Once the buccal tubes were in position, the curing procedure was completed in 20 seconds utilizing a 1000W LED light curing device (5 seconds for each of the occlusal, gingival, mesial and distal surfaces). The LED tip was held at a 45-degree angle and kept as close to the samples as feasible.[8] For Enhance LC (Fig 2), the same procedure was repeated in all three groups and additional application of silane coupling agent (Ultradent) was done in Group III. Initially, the bond strength was evaluated by debonding the metal brackets with INSTRON universal testing machine (Fig 3) crosshead having a speed of 1mm/min aiming at enamel-composite interface. This force was expressed in Newtons and converted to Mega Pascal. The adhesive remaining on the surfaces was also evaluated using Modified adhesive remnant index scores using a stereomicroscope (Fig 4) under 10X magnification. Modified Adhesive Remnant Index scores as follows: Score 0 (No adhesive left on the tooth), Score 1 (1%–25% of adhesive left on the tooth), Score 2 (26%–50% of adhesive left on the tooth), Score 3 (51%–75% of adhesive left on the tooth), Score 4 (76%–99% of adhesive left on the tooth), Score 5 (All adhesive left on the tooth with the distinct impression of bracket mesh).[11-12]

Statistical Analysis:

The collected data were analyzed with SPSS 16.0 Version. Shear Bond strength values and ARI scores did not follow normal distribution. Thus, non-parametric tests such as Kruskal-Wallis test and Mann-Whitney U test were used to assess.

Table 1a: Comparison of mean bond strength of ENHANCE LC on different crown surfaces.

ENHANCE LC	Enamel surface (Group I)	Zirconia surface(Group II)	Ceramic surface (Group III)	P Value (Kruskal-Wallis test)
	12.15±4.23	11.89±4.43	9.65±3.33	0.503

P value = 0.503.

- The findings indicate that Enhance LC showed highest bond strength on Enamel surface (Group I), followed by Zirconia surface (Group II) and Ceramic surface (Group III) respectively. However, it was not statistically significant.

Table 1b: Comparison of mean bond strength of ASSURE PLUS on different crown surfaces.

ASSURE PLUS	Enamel surface (Group I)	Zirconia surface(Group II)	Ceramic surface(Group III)	P Value (Kruskal Wallis test)
	13.01±1.85	12.39±2.37	10.31±3.29	0.015*
P Value (Mann Whitney U test)		0.011*	0.035*	

*p value = 0.015, Statistically significant.

- Assure plus showed similar results with highest bond strength on Enamel surface (Group I), followed by Zirconia surface (Group II) and Ceramic surface (Group III) respectively which are statistically significant.
- Mann Whitney U test showed Assure plus bonded better on Zirconia (Group II) compared to Ceramic (Group III).

Table 1c: Comparison of mean bond strength between ASSURE PLUS and ENHANCE LC bonding agents within the group.

GROUPS		Shear bond strength Mean ± SD	Mann-Whitney Test	P value
Enamel surface (Group I)	IA	12.15±4.22	35.00	0.257
	IB	13.01±1.85		
Zirconia crowns (Group II)	IIA	11.89±4.44	42.00	0.545
	IIB	12.39±2.37		
Ceramic crowns (Group III)	IIIA	9.65±3.33	49.00	0.940
	IIIB	10.31±3.29		

Variables are asymmetrically (non-normally) distributed.

- Assure plus showed greater bond strength than enhance LC on all type of surfaces.
- However, there is no statistically significant difference.

Table 2a: Comparison of mean ARI Scores of ENHANCE LC on differentcrown surfaces.

	Enamel surface (Group I)	Zirconia surface (Group II)	Ceramic surface (Group III)	P Value (Kruskal Wallis test)
ENHANCE LC	2.20±1.98	1.60±2.011	0.60±.52	0.111

P value=0.111.

- The findings indicate that Enhance LC showed highest ARI on Enamel surface (Group I), followed by Zirconia surface (Group II) and Ceramic surface (Group III) respectively. However, it was not statistically significant.

Table 2b: Comparison of mean ARI Scores of Assure plus bonding agent on differentcrown surfaces.

ASSURE PLUS	Enamel surface (Group I)	Zirconia surface (Group II)	Ceramic surface (Group III)	P Value
	3.10±1.59	1.30±1.49	1.21±1.39	(Kruskal-Wallis test)0.015*
P Value (Mann Whitney U-test)	0.015*		0.011*	

*p value 0.015, Statistically significant.

- Assure plus showed similar results with highest ARI Scores on Enamel surface (Group I), followed by Zirconia surface (Group II) and Ceramic surface (Group III) respectively which are statistically significant.
- Mann Whitney U test showed Assure plus bonded better on Zirconia (Group II) compared to Ceramic (Group III).

Table 2c: Mean ARI scores comparison between ASSURE PLUS and ENHANCE LC on different crown surfaces.

		Mean	**Mann-Whitney U**	**P value**
GROUP I (ENAMEL)	IA	2.20±1.98	33.5	0.195
	IB	3.10±1.59		
GROUP II (ZIRCONIA)	IIA	1.60±2.011	49.0	0.937
	IIB	1.30±1.49		
GROUP III (CERAMIC)	IIIA	.60±.51	41.0	0.460
	IIIB	1.20±1.398		

- Assure plus showed highest mean ARI scores on Ceramic surface (Group III) while Enhance LC had higher ARI scores on Zirconia surface (Group II) with no significant difference.

DISCUSSION:

Newer bonding agents were available in the market with limited research on their shear bond strengths on artificial crown surfaces. There is a need to study those characteristics to know their suitability for orthodontic use. The present study compared the shear bond strength (SBS) and Modified ARI scores of two bonding agents (Assure Plus & Enhance LC) on three different crown surfaces. The results revealed that the Assure plus had a superior bond strength when compared with Enhance L.C. on enamel, followed by zirconia surface, out of which the Assure plus on the enamel group has the highest shear bond strength with statistical significance.

On enamel surface, the current study found that the mean bond strength of Assure Plus was 13.011.85Mpa, consistent with the findings of Toodehzaeim et al.,[6] who found that Assure Plus had a bond strength of 14.52Mpa. In dry conditions, G E Amirabadi et al.[13] also achieved a similar bond strength of 14.78 MPa. Similar results could be possible because of the etching of enamel with 37% phosphoric acid in both studies. On the contrary, Littlewood et al.[14] reported that although hydrophilic primers were used, they had decreased bond strength of 6.3±3.2Mpa compared to conventional primer Transbond (8.7-12.1 MPa) because all the tests were done under dry conditions.

The presence of water has increased bond strength. On feldspathic ceramic crowns. The current study showed a mean bond strength of 13.34 MPa for Assure Plus. In their study, Roya Naseh et al.[15] reported a slightly higher bond strength of 15.71MPa on feldspathic porcelain. This might be due to additional sandblasting followed by etching of ceramic surface with 9.6%H.F**.** up to 2 minutes. Sandblasting, followed by etching with hydrofluoric acid, attacks the glass phase of ceramics, exposing silica oxides for chemically bonding with Assure Plus. The silanol (Si-OH) group of the primer and the O.H. group of the ceramic combine to liberate a water molecule and, in the process, form a stable siloxane (Si-O-Si) bond. On the opposing, Toodehzaeim et al[6] supported much lower bond strengths of 8.85 MPa, because the surface was only sandblasted, without any etching, unlike the present study, where the ceramic surface was etched with 9.6% H.F. followed by the application of a silane coupling agent.

The present study showed Assure Plus achieved a mean bond strength of 14.47 MPa on zirconia crowns. In contrast to Ceramic, Zirconia does not contain a glass phase and etching the zirconia surface with hydrofluoric acid does not enhance bond strength. Bonding mainly occurs by physicochemical conditioning involving air abrasion exposing silica oxides for chemically bonding with Assure Plus. This is one significant advantage of this bonding agent to other materials.[16]

Douara et al.[17] found the highest bond strength of 10.01MPa in one group of Assure plus, which was treated with Air abrasion followed by silane application. Because in silane, the alkoxy group undergoes a hydrolysis process and reacts with the hydroxyl of the filler surface by hydrogen bond formation. Then, Si–O cross-links are formed between the filler surface and the adjacent functional groups in a condensation reaction forming a stronger bond. On the contrary, the group treated only by air abrasion showed the lowest shear bond strength of 1.36– 3.69 MPA. It can be assumed that Assure Plus alone is not enough to bond to glazed zirconia since conservative surface treatments such as air abrasion do not guarantee the complete removal of the glaze and the exposure of underlying zirconia. Similar results were reported by both Lee J. H. et al [18] and Kwak et al.[19]

SHEAR BOND STRENGTHS OF ENHANCE LC:

Another bonding agent used in the study is the Enhance L.C. (Reliance, Itasca, Ill), an adhesion booster, a tooth surface primer advocated by Bowen et al.[11] to strengthen the bond between composite resin and tooth surfaces. Previous studies[20-22] have reported that Enhance-LC increases the adhesion of composite to any enamel (including fluoresced, hypocalcified, or deciduous enamel), metal, or composite surface. It contains hydroxyethyl methacrylate (HEMA), tetrahydro furfuryl cyclohexane dimethacrylate, and ethanol. The HEMA molecule has double functional groups, one hydrophobic and the other hydrophilic. Hydrophilic monomers in these adhesive systems facilitate resin infiltrating etched enamel at the level of the enamel prisms. This property can potentially reduce interfacial porosity and hence increase adhesion, achieving superior shear bond strength through polymerization.[15]

In the present study, the mean shear bond strength obtained using Enhance L.C. on normal enamel was 12.15±4.22 MPa. Vicente et al.[23] obtained the mean bond strength values of Enhance L.C. with Transbond XT (12.67MPa), similar to the present study. The mean bond strength values are in agreement with a slight difference of 0.43MPa, which is negligible and not specific because both studies were done similarly.

Chun-Hsi Chung et al[24] Suggested that the bond strength of new brackets with Enhance L.C. had a bond strength of 18.6MPa. While rebonded brackets with Enhance L.C. had a bond strength of 13.6 MPa. Sandblasting the new brackets base has increased the bond strength to enamel by removing unfavorable oxides, contaminants on the base and increasing surface roughness and surface bonding area. An organosilane, biphenyl dimethacrylate resin (BPDM), and an NTG-GMA bond accelerator are used in this new-generation bonding agent. To provide a complete cure, BPDM and NTG-GMA resin work by increasing the wettability of the porcelain and accelerating the cure of the overlying composite resin.

Enhance L.C. on ceramic crowns bonded with buccal tubes demonstrated a mean shear bond strength of 9.653.33MPa in the current study. Paul W. Major et al.,[25] compared the bond strength of three different types of adhesion promoters: Porcelain Primer, All-Bond 2, and Scotch Prime Ceramic Primer (S.P.) When used with Rely-A-Bond adhesive, the adhesive booster all bond 2 demonstrated a mean bond strength of 4.34 MPa ranging from 2.19-7.73MPa and a mean bond strength of 8.40MPa ranging from 2.72-15.05 MPa. The values obtained in this study were in no way comparable because H.F. acid was not used at a concentration or time sufficient to achieve significant etching but rather to acidify the alkaline layer of water at the surface and hopefully achieve some etching effects as well. On Zirconia crowns bonded with buccal tubes demonstrated a mean shear bond strength of 11.894 MPa in the current study. There has been no research into the bond strength values of Enhance L.C. on zirconia crowns. According to the study's findings, the adhesive booster had acceptable shear bond strength and could be used for zirconia crowns.

ARI SCORES OF ASSURE PLUS:

On the enamel surface, the current study reported that Assure Plus had a score of 5 in 30% of extracted teeth. On the contrary, G E Amirabadi et al.[13] found that 40% had an ARI score (2) for assure plus group on the enamel surface. However, higher scores of ARI were recorded in the current study suggesting unfavorable bonding at the bracket

adhesive interface. It is likely due to the creation of bubbles under the brackets, reducing the enamel-bracket bond strength and increasing failures in this area.

On the ceramic surface, most of the sample showed (40%) had an ARI score of 0. Similar results were obtained by Roya Naseh et al.,[15] where 40% of specimens had an ARI score of 0, indicating cohesive failure within the porcelain. However, 30% of the remaining groups showed 90–100% cohesive failures, which might be attributed to structural differences of ceramics and higher fracture strength of lithium disilicate ceramic. On the zirconia, surface shows that 30% of extracted teeth had an ARI score of 0. Results were in concordance with the study by Douara et al.,[17] the group which was treated only by air abrasion without any silane. Unlike the present study, the failure occurs at the zirconia-adhesive interface due to the bonding protocol.

ARI SCORES OF ENHANCE LC

On the enamel surface, Enhance L.C. reported that 40% of extracted teeth had an ARI score of 5. Vicente et al.[23] obtained the mean ARI scores of 2 for 80% of the samples. It is due to the additional treatment of the enamel surface by the silane coupling agent in the current study. On ceramic and zirconia surfaces, 60% of extracted teeth had an ARI score of 1, and 40% of extracted teeth had an ARI score of 1, respectively. No literature study evaluated the ARI scores of Enhance L.C. on ceramic/zirconia crowns. According to the study's findings, the adhesive booster had acceptable ARI scores and could be used for ceramic/zirconia crowns**.**

CONCLUSION:

Assure Plus and Enhance L.C. provided a strong bond on ceramic and zirconia surfaces. Thus, Assure Plus is a better option for repeated bond failures in patients with zirconia prostheses on molars.

LIMITATIONS OF THE STUDY

1. The thickness of adhesive on the molar tube could not be quantified and varied from tooth to tooth.

2. The test conditions of the present study cannot be directly compared to the complex intra-oral environment. This applies to all in-vitro studies**.**

SOURCE OF FUNDING

Nil in terms of financial assistance or sponsorship

CONFLICTS OF INTEREST

No conflicts of interest exist

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