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ORIGINAL RESEARCH

Lingual Bracket Systems with Self Etching Primers—An *In Vitro* Study to Evaluate Shear Bond Strength

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ABSTRACT

Aim: To evaluate the shear bond strength of orthodontic lingual bracket systems bonded to extracted premolar teeth (Reliance self-etching primer, Clearfil Protect Bond) and self-etching primer (Clearfil SE Bond)

Materials and methods: A total of 160 extracted human first premolars were selected and divided into four groups of 10 for each bracket system to be used with four different primers. Each sample was then embedded in an acrylic block, till the coronal portion. Instron testing machine model LR LOYD 50 K was used for testing the shear bond strength.

Results: The results obtained, suggested that all the primers had clinically acceptable shear bond strength with all the bracket system considered in the study. However, there were statistically significant differences in the shear bond strength in intergroup comparisons.

Conclusion: The Reliance Self-Etching primer showed the highest bond strength with Alias lingual bracket system by Ormco, followed by clearfil protect bond, clearfil SE bond, and transbond, with the Alias lingual bracket system in the same order.

Clinical significance: This study was initiated to understand the shear bond strength of self-etching primer and its efficacy over the conventional primer, which will be of use to the clinician while selecting the primer for bonding of the bracket systems and overcome debonding of brackets encountered during the treatment progress.

Keywords: Self-etching primers, Self-ligating lingual brackets, Shear bond strength, Tooth surface demineralization.

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INTRODUCTION

Over the past decade, researches have been directed towards a more patient-oriented, clinician-friendly bracket systems, to enhance the quality of treatment provided. Orthodontists are more often being approached for aesthetic needs rather than the underlying functional defects. Therefore, esthetics becomes the prime factor to address, when patient acceptance of the appliance comes into the picture. The development of lingual bracket system itself was a major leap in the treatment mechanics to provide an inconspicuous appliance and it rapidly gained popularity among the patients and clinician equally. The introduction of lingual brackets widened the options available to the clinician, as well as fulfilled the aesthetic requirements of the patients, almost completely. One of the major difficulties that the system encountered was the bonding to the tooth surface, due to the moisture-laden field of adhesion. Although different techniques have been put forward to solve this problem, indirect bonding remains the method of choice. In this study, the shear bond strength of various lingual systems was compared with four different primers, to give an insight into the adhesive

capability of the primers and the longevity of the brackets systems with these primers.

There was a rise in the practicality that was being provided to the orthodontist in terms of optimization of Laboratory process,[1] chairside processes,[2] computerized archwire fabrication and much more.[3] Difficulties have been reported with the use of lingual bracket systems, ranging from speech dysfunction, restricted mastication, oral discomfort to oral hygiene problems.[4] Almost all the problems reported, were in association with prefabricated lingual brackets.[5] To overcome this, customized brackets are doing the rounds in the research tables and in the clinician's armamentarium to provide the solution for the various problems encountered.[6] Customized brackets are obtained from scanning the study models using high-resolution three-dimensional scanners. These brackets are then designed individually by computer technology and subsequently fabricated by means of rapid prototyping.[7]

The bracket bases which are 0.4 mm thick are contoured to the lingual surfaces of the teeth which also permits direct (re-) bonding. Direct bonding of orthodontic attachments is a routine clinical process.[8]

It was Buonocore in 1955, who demonstrated the adhesion of acrylic filling materials to enamel, following acid etching by phosphoric acid. Newman in 1965, suggested that the technique might be used for orthodontic bonding.[9] Among the various modalities that are being under research, phosphoric acid still seems to hold the edge in enamel surface preparation, although it is found to cause the demineralization of the most superficial layer of enamel.[10]

AIMS AND OBJECTIVES

The aim of the present study was:

- To evaluate the shear bond strength of Orthodontic Lingual Bracket systems bonded to extracted premolar teeth with self-etch primer, Reliance Self Etching Primer, Clearfil Protect Bond, Clearfil SE Bond and Transbond.
- To compare the mean bond strength values of various primers with the different lingual bracket systems used.

MATERIALS AND METHODS

Total 160 freshly extracted human first premolars were collected and stored in a solution of 0.1% (weight/volume) thymol solution, for 15 days to prevent dehydration and bacterial growth.

Inclusion Criteria

- Freshly extracted first premolar teeth
- Intact enamel surface
- No evident caries
- No visible cracks

The teeth were fixed in acrylic self-cure blocks such that the roots were completely embedded in acrylic up to the cementoenamel junction, to simulate the clinical crown height.

Distribution of Sample

Teeth were divided into four groups of 40 samples each. Each group was then subdivided into four subgroups based on the different orthodontic lingual bracket system used with 10 samples each.

- *Group I (TP):* Transbond Plus (3M Unitek, Monrovia, Calif) (Fifth generation) (Fig. 1A)
- *Group II (SE):* Clearfil SE Bond (Kuraray, Osaka, Japan) (Fifth generation) (Fig. 1B)
- *Group III (CP):* Clearfil Protect Bond (Kuraray, Osaka, Japan) (Sixth generation) (Fig. 1C)
- *Group IV (RSEP):* Reliance Self etching Primer (Reliance Orthodontics) (Sixth generation) (Fig. 2)

Bracket Systems Used

- 7th Generation (Ormco) (Fig. 3A)
- STb (Fig. 3B)
- Incognito (Fig. 3C)
- Alias (Ormco) (Fig. 3D)

Light Curing Unit

3M Curing light 2500 (3M Dental Products) with an intensity of 480 nm was used for polymerization for 20 seconds. Each bracket was cured for 4 seconds of gingival, 4 seconds from occlusal, 4 seconds from mesial, 4 seconds from distal and 4 seconds interproximally.

Adhesive

Transbond XT was used for bonding all the four groups.

Incubation

The samples were stored in deionized water at 37°C for 24 hours before debonding.

The Instron Universal testing machine (Model No. LR LOYD 50K-UK)was used to carry out the test for shear bond strength.

Bonding Procedures

The lingual surface of all teeth was pumiced and thoroughly rinsed with distilled water. The tooth surfaces were dried and isolated to avoid contamination of the treatment area.

Primer liquid was dispensed into the mixing dish, immediately before application and was applied gently

Figs 1A to C: (A) Transbond plus; (B) Clearfil SE bond; (C) Clearfil protect bond

Fig. 2: Reliance self-etching primer

and dried with mild airflow. The required amount of the bond was dispensed into a mixing dish and applied to the primed area. After applying bond, a uniform bond film was created using a gentle oil-free airflow; it was light-cured for 10 seconds with curing light. Bracket with adhesive was placed on the tooth surface and firmly pressed in place and was light-cured for 20 seconds with visible light curing unit.

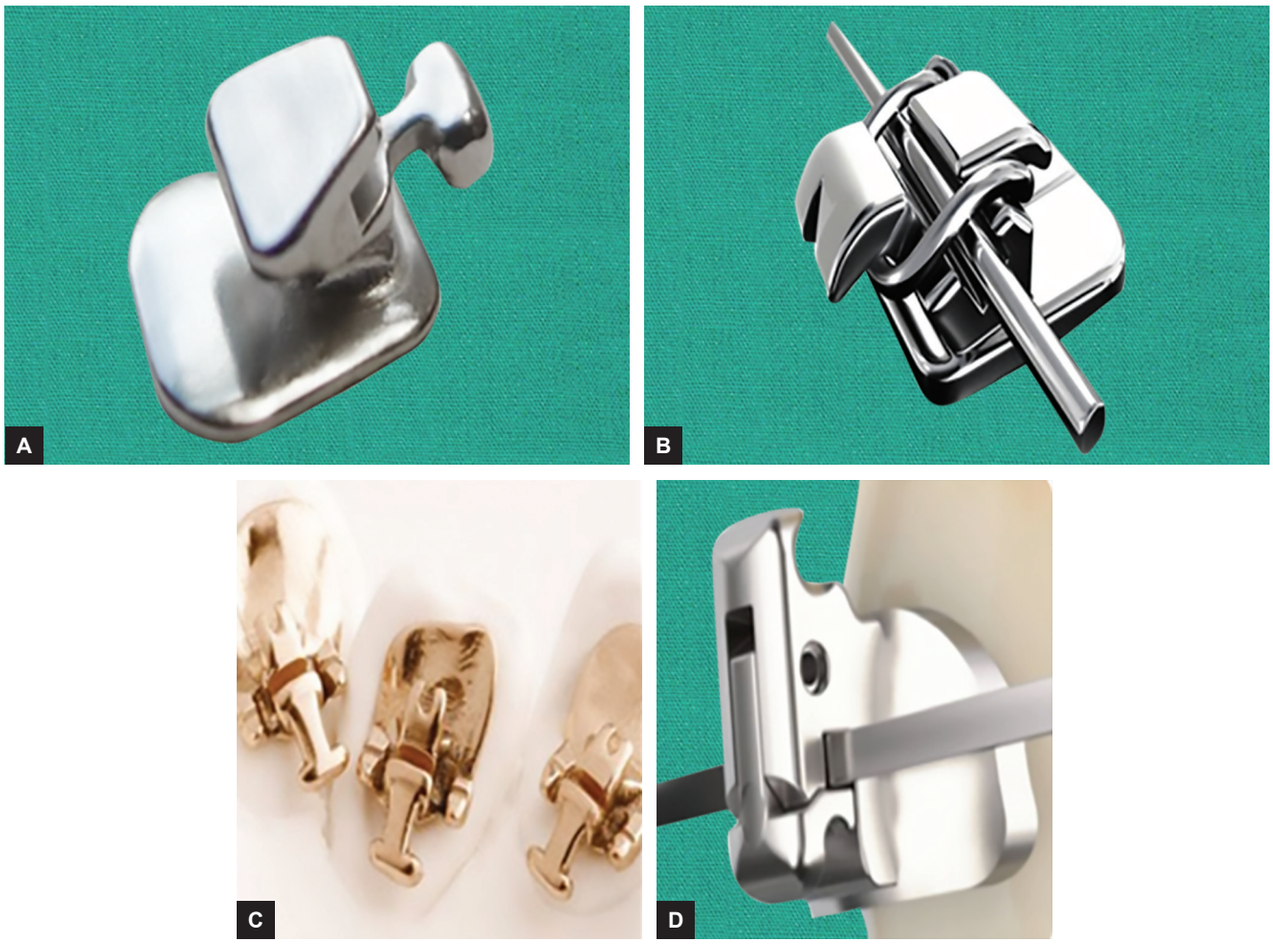
Bond Strength Testing

The shear bond strength of bonded specimens was tested after 24 hrs of bonding in an Instron testing machine model LP50K with a crosshead speed of 0.5 mm/min.

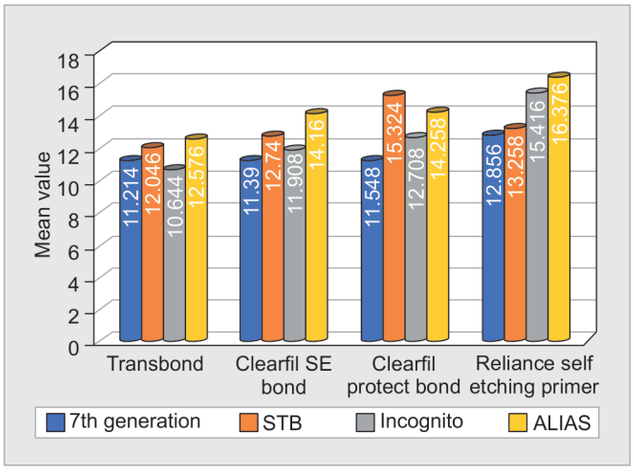
The acrylic block mounted with specimen was secured to the lower grip of the machine (fixed head) and a custom-made grip was placed in the upper grip (movable head) connected to the load level and the blade was positioned in such a way that it touched the bracket.

The crosshead speed was adjusted to 0.5 mm/min and the force at which the bracket debonded was recorded. The bond strength was calculated in Mega Pascals by using the following formula.

Shear Bond strength in MPa = Force in Newton/
Surface area of the bracket in mm^2



Figs 3A to D: (A) Seventh generation; (B) STb; (C) Incognito; (D) Alias



Graph 1: Comparison of mean bond strength of transbond, clearfil SE bond, clearfil protect bond, reliance self etching primer with various lingual bracket systems

Statistical Analysis (Table 1 and Graph 1)

The single step, multiple comparison procedure, and statistical test, Tukey test was used in conjunction with an ANOVA (post-hoc analysis), to find means that are significantly different from each other. F-test was used to compare the statistical models. These statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 17.0 software.

Table 1: Multiple comparisons

ANOVA			
Bond strength			
CLASS		*F*	*p*
7th generation	Between Groups	456.834	<0.001 vhs
STB	Between Groups	845.519	<0.001 vhs
Incognito	Between Groups	3403.556	<0.001 vhs
ALIAS	Between Groups	1442.058	<0.001 vhs

RESULTS (TABLE 2)

- Reliance Self Etching Primer gave superior results with all the bracket systems under the study.
- Alias self-ligating lingual brackets displayed an increased shear bond strength with all the primers that were considered in the study.
- The mean bond strength among 4 groups was found to be highly significant. Maximum bond strength was found in Reliance Self Etching Primer used along with Alias self-ligating lingual Bracket system and minimum bond strength was observed with

Table 2: Comparison of mean bond strength among different groups

Class		*N*	*Mean*	*Std. Deviation*	*Minimum*	*Maximum*
7th generation	Transbond	10	11.214	0.105	11.11	11.33
	Clearfil SE Bond	10	11.390	0.065	11.29	11.47
	Clearfil Protect Bond	10	11.548	0.054	11.47	11.60
	Reliance Self Etching Primer	10	12.856	0.079	12.76	12.96
STB	Transbond	10	12.046	0.133	11.90	12.22
	Clearfil SE Bond	10	12.740	0.046	12.67	12.80
	Clearfil Protect Bond	10	15.324	0.143	15.10	15.50
	Reliance Self Etching Primer	10	13.258	0.083	13.16	13.37
Incognito	Transbond	10	10.644	0.062	10.58	10.72
	Clearfil SE Bond	10	11.908	0.052	11.84	11.98
	Clearfil Protect Bond	10	12.708	0.084	12.61	12.81
	Reliance Self Etching Primer	10	15.416	0.101	15.32	15.57
ALIAS	Transbond	10	12.576	0.104	12.43	12.72
	Clearfil SE Bond	10	14.160	0.051	14.08	14.22
	Clearfil Protect Bond	10	14.258	0.124	14.07	14.40
	Reliance Self Etching Primer	10	16.376	0.070	16.30	16.45

Transbond primer used along with the incognito lingual bracket system.

- The Shear bond strength of reliance self etching primer was highest when used with the Alias Self-ligating lingual bracket system as compared to all other combinations used within each group.

DISCUSSION

The basic foundation of lingual appliance design is opening of the archwire slots to the occlusal aspect rather than to the lingual aspect. The occlusal approach makes arch wire insertion, seating, and removal easier than arch wire insertion with lingually opening slots. The first 1 mm of the molar tube opens to the occlusal aspect which provides direct guidance for insertion of the archwire occlusal to the archwire plane. As the ends of the archwire are inserted into the tubes, the rest of the archwire moves gingivally directly into the occlusal opening of the bracket slots. But the lingually opening slots require insertion of the archwire distally beyond anterior brackets, constriction of the archwire lingually to engage premolars lots, and then bringing of the archwire mesially, to fully engage the anterior brackets. This explains the reason for the difficulty in placement and removal of stiffer archwires in lingually opening archwire slot. This also provides an additional benefit, that the archwire will not pull out of the slot with space-closing mechanics. This eliminates the special time-consuming ligation techniques (double-over ties) necessary for lingually opening slots.

The occlusal design approach did have potential problems that had to be solved: specifically, a design of premolar and molar brackets that would provide effective ligation, a design of anterior brackets for a better quality of ligation, and design of all brackets that would provide adequate tip control. This was overcome by the design of premolar and molar brackets, with occlusal tie wings projecting mesially and distally instead of labiolingually. These tie wings change the direction of the ligature pull 90°, thereby helping in effectively seating the archwire in the bottom of the slot. Anterior brackets use this same design feature to enhance the quality of their ligation. The occlusal tie wings have mesial and distal undercuts that parallel the bottom of the slot. They also change the direction of the pull of the ligature to seat the archwire into the bottom of the slot.

The bond strength plays a crucial role in the properties expressed by the bracket system, as they provide stability to the bracket base. The treatment results were found to be significantly higher in mechanisms involving better adhesive properties.[11] Various evolutions, in terms of adhesives used in the bonding procedures, have provided the platform for an improved direct bonding technique in Orthodontic clinical setup.

The introduction of lingual appliances flocked the patients to the dental office for invisible braces. This was an exciting development in the field of orthodontics but demanded rigorous attention to technique, a requirement that every practitioner could not handle without special training. The lingual appliances have several clear-cut advantages over the labial appliances from the patient's point of view:

- Facial surfaces of the teeth are not damaged from bonding, debonding, adhesive removal or from the plaque retained areas around the braces,

- Better health of gingival tissues,
- They can appreciate the changes in the tooth position as the view is not hindered by the appliance,
- Facial contours can be truly visualized as the contour and drape of the lip is not distorted by the protruding labial appliance.

Some of the inherent disadvantages of lingual appliances are (A) Brackets are attached to very irregular and inconsistent lingual surfaces, which are not the surfaces to be aligned, (B) The vertical height of the brackets vary with the torque angles of the labial surface, (C) These factors make the placement of the pretorqued brackets in the maxillary incisor region, very inaccurate. More accurate indirect bonding procedures for bracket placement is resolving these disadvantages.

In the study conducted by Lorenzoni et al on the bond strength of Z-PRIME Plus containing biphenyl dimethacrylate and hydroxyethyl methacrylate and Monobond Plus largely comprising of silane methacrylate, 10-methacryloyloxydecyl dihydrogen phosphate (MDP) and sulphide methacrylate, they reported that Z-PRIME Plus displayed lower bond strength as compared to MDP containing primers because the carboxylic acid monomer of Z-PRIME Plus weakened the bonding with the methacrylate group of the resin cement. Similar results were reported by Koizumi et al., that the sulfide methacrylate monomer in Monobond Plus affects bond strength. Ji-Yeon Lee et al. reported that, regardless of thermocycling application, the groups without primer showed lower shear bond strength and adhesive failure compared to the groups using zirconia primers. But in our study, the shear bond strength with various self-etching primers gave significantly higher values, even without thermocycling.

Ashtekar et al. reported that Lingualmatrix bracket was superior to 7th generation and STb brackets, although there was no significant difference between the Shear bond strength of 7th generation and STb brackets, which was similar to our study. Lombardo L et al. reported that the bonding technique did not seem to exert a great influence on bonding success and the bracket-adhesive interface was identified as the area most prone to failure.

Therefore, this study was undertaken to understand the variation in the bond strength between the various adhesives and the lingual bracket systems that were available at present. Conventional adhesive systems use three different agents (an enamel conditioner, a primer solution, and an adhesive resin) in the process of bonding orthodontic brackets to enamel. Combining conditioning and priming into a single treatment step results in improvement in both time and cost effectiveness to the clinicians and indirectly to the patient. Contemporary self-etching primers, which were introduced in the 1990s, and the recently introduced 'all in one adhesive' are attractive additions to the clinician's bonding armamentarium. They are user-friendly, in that the number of steps required in the bonding protocol is reduced. As the smear plugs are not removed before the application of these adhesives, the potential for postoperative sensitivity that is caused by incomplete resin infiltration of patent dentinal tubules can be substantially reduced.

In the self-etching primer, the active ingredient is a methacrylate phosphoric acid ester. The phosphoric acid and the methacrylate group are combined into a molecule that etches and primes at the same time. Etching and monomer penetration to the exposed enamel rods is simultaneous. In this manner, the depth of the etch is identical to that of the primer penetration.

There seems to be only one recent self-etching adhesive product (Transbond plus 3M Unitek, Monrovia, California) designed especially for the orthodontic purpose, most of the previous bond strength studies tested various self-etching adhesives used in restorative dentistry. Despite some encouraging findings, variations in results or methodologies used, necessitate further in-vitro studies before routine use of self-etching adhesives for orthodontic bonding purposes can be advocated. Decalcification around orthodontic bracket is a common problem and a potential risk of orthodontic treatment.[12] Michele BalestrinImakami et al. reported that bonding of lingual brackets to ceramic surfaces exhibited greater shear strength when aluminum oxide was used in association with Transbond XT and Sondhi Rapid-Set, although Transbond XT showed greater shear strength.

The bonding of Lingual Bracket Systems itself is a challenge due to the difficulty in obtaining a moisture free environment and difficulty in maintenance of oral hygiene. Intact enamel surface of the tooth was taken as a criteria for this study, in order to derive a more comprehensive idea of the shear bond strength and to provide uniformity among the samples collected.

Results of the Present Study

- Among the primers used, the Reliance Self Etching Primer exhibited better shear bond strength with all the bracket systems considered in the study.
- With the recent advances in the bracket systems, the Alias Self ligating Lingual Brackets were found to exhibit higher shear bond strength amongst various lingual bracket systems considered in the study.
- Reliance Self Etching Primer showed superior qualities among the tested materials and proved to be cost effective.

Some studies have put forward the conclusion that the surface quality of the bonding surface has an impact on the shear bond strength. Various authors have reported that the surface treatment techniques of the bases of lingual brackets have enhanced the adhesive capability and thereby the shear bond strength of the brackets.[13] This study mainly deals with the self-etching primers influencing the shear bond strength and being an *in vitro* study, has its own limitations in the clinical scenario. The results impart an understanding of the strength of various primers and the lingual bracket systems. More research in this regard, on a clinical basis, will prove to be more effective and will overcome this limitation of the study.

CONCLUSION

This study could clearly identify the evolution of various primers and the bracket system in a single study. The primers gave a constant increase in properties from early to latest inventions in the field. The improvement in the lingual bracket systems also provided worthy contributions to the exhibition of superior properties by the appliances.[14] The Reliance Self Etch Primer used along with the Alias Self Ligating Lingual Brackets provided the higher shear bond strength amongst the samples considered in the study. This study also strengthens the results that primers provide a better bracket-adhesive interface and self-etching primers are better in that aspect. The evolution of various primers and the bracket system can be easily identified in a single study.

The primers gave a constant increase in properties from early to latest inventions in the field. The improvement in the lingual bracket systems also provided worthy contributions to the exhibition of superior properties by the appliances.[14] Most the studies have concluded that there is a significant difference in the shear bond strength when the surface characteristics of the bracket systems changes. There are reports of improvement in the bond strength when primers are used at the bracket-adhesive interface.[15]

The clinical significance of this study is aimed at identifying the difference in shear bond strength of various primers that are available at present and thereby guide the clinician in reducing the failure rate of bonding.

There is still research going on in the field to improve the strength of the materials and to provide a near flawless material with improved bond strength, to avoid any inter appointment debonding of the brackets. More research in this aspect might prove to be beneficial to the patient and the clinician so that the quality of care is never compromised. It is found that the lingual brackets have the same capacity to align the teeth, just as the labial brackets. The designing of the appliance system, with a precise understanding of the technique and proper use of the materials, yielded the best results.

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