Evaluation of shear bond strength of different orthodontic primers on natural teeth – An *in-vitro* study

Bommanna Logesh S B[1], M. Karthi[2*], A. Raja[3], S. Raja[4], K. Prabhakar[5], Revathy S[6]

[1]Post Graduate, [2,5-6]Professor, [3]Professor and Head, [6]Senior Lecturer [1-6]Dept. of Orthodontics and Dentofacial Orthopedics, [1-6] KSR Institute of Dental Science and Research, Thokkavadi, Tamil Nadu, India

Corresponding author: M. Karthi*
Email: drkarthiortho@gmail.com

Abstract

Aim and Objective: The aim of this study was to evaluate the Shear Bond Strength of three different Hydrophilic primers available in the market compared with a conventional hydrophobic Primer and also to evaluate the amount of residual adhesive resin on the enamel surface after debonding using ARI Index.

Matrials and Methods: Hundred natural premolar teeth extracted for orthodontic treatment were included in this study. This study compared the Shear Bond Strength of three different hydrophilic primers namely Transbond MIP (3M Unitek), OrthoSolo (Ormco) and Stedman (Anabond) under salivary contaminated conditions with the standard hydrophobic Primer (Transbond XT – 3M Unitek) under dry conditions. The natural premolar teeth were equally divided into four groups namely Group A, Group B, Group C and Group D with 25 teeth in each group mounted in acrylic blocks. The teeth in these groups were bonded with three different hydrophilic primers [Transbond MIP (3M Unitek), OrthoSolo (Ormco) and Stedman (Anabond)] respectively after salivary contamination. All the premolars were bonded with 0.022 MBT metal Brackets. A light cure unit (Ivoclar Vivadent) was used to cure the adhesive. For Salivary contamination on the teeth after acid etching, the operator's saliva was collected by Spitting Method in a test tube and used. The bonded teeth were subjected to evaluation of shear bond strength using a Universal Testing Machine. After debonding, ARI scores on the Enamel Surface were evaluated using the Stereomicroscope under 10X magnification. The results of the shear bond strength were measured in Megapascals and tabulated for Statistical analysis. Shapiro Wilks Test was performed to evaluate the normality of the distribution, Kruskal Wallis Test was done to identify the association between various groups. Chi Square test was done to find the association between groups for ARI scores.

Results & Conclusion: The results showed that based on p value, all the primers are highly statistically significant in achieving the acceptable shear bond strength. Under contaminated condition, Transbond MIP (3M Unitek) showed highest mean shear bond strength of about 12.24 MPa followed by OrthoSolo primer (Ormco) and the lowest shear bond strength by Anabond Stedman primer. Transbond XT showed mean shear bond strength of 9.22 MPa under dry condition. Based on Post hoc dunn's Test, there was no significant difference between individual groups except between Group B (Transbond MIP) and Group D (Anabond Stedman) & Group B (Transbond MIP) and Group C (OrthoSolo) which showed statistically significant difference of $p<0.05$. The primers showed majority of bond failure at the adhesive bracket interface resulting in reduced enamel fracture with highest percentage exhibited by Transbond XT(84%) followed by OrthoSolo(68%), Transbond MIP(64%) and Anabond Stedman primer(60%). Transbond XT primer showed 0% of frequency of enamel fracture indicating that no bond failure occurred at the adhesive bracket interface resulting in reduced enamel fracture.

Keywords: Shear Bond Strength, Transbond XT, Transbond MIP, OrthoSolo, Stedman, Universal Testing Machine(UTM), Shear Bond Strength(SBS), Adhesive Remnant Index(ARI), Stereomicroscope.

Introduction

Buonocore[1] in 1955 introduced bonding technique called acid etching, which involves the preparation of enamel surface by etching with 37% ortho-phosphoric acid, followed by primer application and adhesive placement. To achieve optimal orthodontic bond strength as advocated by Reynolds,[2] the enamel surface should be dry. This is difficult in cases of posterior teeth, impacted teeth, because in wet environment most of the porosities become plugged and the resin penetration is impaired which results in an insufficient number and length of the resin tags which adversely affects the bond strength. To reduce the problem, (based on dentin bonding agents) hydrophilic primers have been introduced. Hydroxyethyl methacrylate and acetone/alcohol in the bonding agents produces lower contact angle and displaces the moisture from the enamel surface respectively.

The bond strength of Transbond MIP with Transbond XT adhesive under dry, moist, and blood contaminated conditions on human teeth suggested that all bond strengths were greater than required clinically so that Transbond MIP is a suitable primer for bonding in conditions of poor moisture control or blood contamination.[3] Moisture insensitive primer is effective in the presence/absence of moisture and has shown SBS value of more than 7.8 Mpa, hence the material is suitable for clinical use.[4]

Ortho Solo is a fluoride-releasing universal sealant and bond enhancer. It is composed of dimethacrylate resins, barium glass, fumed silica, sodium hexafluorosilicate, and ethanol. OrthoSolo produced best results and reduced remnant adhesive similar to that of Transbond XT, when used with Transbond XT adhesive.[5] Orthofix adhesive with Stedman primer is a new hydrophilic material and is less expensive, which contains Bis-GMA/ TEGDMA matrix with barium glass fillers and fumed silica. On comparing Transbond XT and Orthofix, the overall bond failure rate and mean survival time for Orthofix was similar to Transbond XT.[6]

This study was undertaken with the following objectives:

1. To evaluate and compare the shear bond strength of various Hydrophilic primers(Transbond MIP,

OrthoSolo, Stedman Anabond) in contaminated conditions with the Standard Hydrophobic primer (Transbond XT) under dry conditions;
2. To study the debonding characteristics and bond failure of specimens bonded with the above primers using Adhesive remnant index.

Materials and Methods

The study sample consisted of 110 natural premolar teeth.

Exclusion criteria

- Teeth with Dental Caries and or restorations
- Teeth with any grade of Hypoplasia/Fluorosis or enamel cracks
- Developmental Anomalies

The collected teeth were stored in 10% formalin solution. 100 teeth were selected and split into 4 groups Group A, Group B, Group C and Group D comprising of 25 teeth each and then mounted on coloured acrylic blocks with each block comprising of 5 teeth each. (Fig.1). Natural saliva was collected (Fig. 3) after chlorhexidine oral rinse for 5 minutes using Spitting method according to Yamuna Priya et al.[7] The Spitting method allows the subject to accumulate saliva in the floor of the mouth and spit into sterilized graduated collecting tube. The teeth were thoroughly cleaned free of debris and pumice polished. 37% Orthophosphoric acid – Scotchbond (3M) was applied and etched for 30 seconds for all the sample teeth in all Groups. Distilled water was used to rinse the etchant and the teeth were air dried using chip blower until a white frosty appearance was obtained. For group A teeth, Transbond XT Primer – 3M Unitek (Fig. 2) was applied over the etched surface using blotting technique. The Premolar brackets (3M Unitek Gemini) were bonded with Transbond XT (3M Unitek) adhesive. The etched surface of Group B, C and D were contaminated with the collected saliva by applying a layer of saliva over etched surface using disposable brush for 5 seconds. Transbond MIP (3M Unitek) (Fig. 2), Orthosolo (Ormco) (Fig. 2) and Stedman (Anabond) (Fig. 2) primers was applied over the contaminated teeth surface respectively. The 3M Gemini brackets were bonded over the teeth using Transbond XT (3M Unitek) for Group A, Enlight (Ormco) and Orthofix (Anabond) adhesives are applied and light curing was done for about 6 seconds mesially and 6 seconds distally using Bluephase N MC (Ivoclar Vivadent). The samples were evaluated for Shear Bond Strength using Universal Testing Machine (Kalpak UTM 121101) for shearing (Fig.4) with a special tool (Fig.5). Load was carefully applied between the bracket and the teeth with crosshead speed of 1mm/min. The area of the mesh of the 3M Gemini Premolar bracket was measured to be 9.61mm. The shear force levels were evaluated and converted into MegaPascal unit. The debonded teeth were subjected to study under Stereomicroscope with 10X magnification and the Adhesive Remnant Index scoring using Artun and Bergland scale.[8] The Shear Bond Strength was evaluated by the formula σ_{shear} – Fmax /A bracket base surface (MPa).

Armamentarium

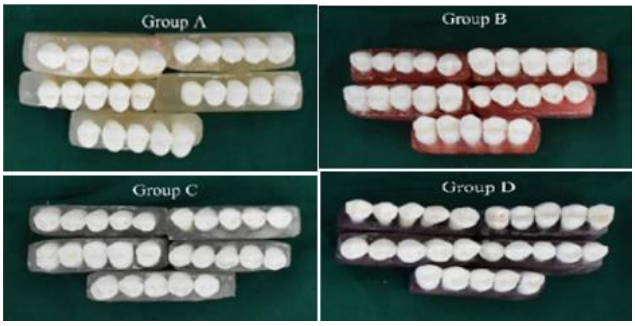

Figure 1: Fabrication of blocks

Figure 2: Materials for bonding

Figure 3: Saliva collection by spitting method

Figure 4: Universal testing machine

Figure 5: UTM application of load over the sample

Statistical analysis

All analysis was analyzed using SPSS Version 25.0 software version. Descriptive statistics were performed. The results were presented as mean, standard deviation median and interquartile range for continuous data. Data was analyzed to assess normality using Shapiro-Wilks test. Based on the distribution of the data, Kruskal–Wallis test with post hoc dunn's test was carried out to analyze the difference between groups. p value <0.05 is considered as statistically significant. Chi Square test is used to determine relationship between two categorical variables. This test is used to determine the association of ARI scores among all groups.

Table 1: Means of shear bond strength of all groups

Groups	Mean Shear Bond Strength	P Value
Transbond XT(A)	9.22 ± 3.3 MPa	0.001*
Transbond MIP (B)	12.24 ± 5.1 MPa	
Orthosolo (C)	9.23 ± 3.7 MPa	
Stedman Anabond (D)	7.86 ± 1.9 MPa	

Kruskal Wallis Test* shows p<0.05

Table 1 showing that there is statistically significant difference in the Shear Bond Strength among the four groups. Group B showed high mean values followed by group C, group A and group D.

Table 2: Post hoc dunn's test showing correlation between individual groups

Groups	Test Statistic	Standard Error	Standard error statistic	Significance	Adj. Significance
Group A-	-18.520	8.205	-2.257	0.024	0.144
Group B					
Group A –	5.020	8.205	0.612	0.541	1.000
Group C					
Group A –	12.620	8.205	1.538	0.124	0.744
Group D					
Group B –	Grp C - Grp B	23.540	8.205	2.869	0.004*
Group C					
Group B –	Grp D - Grp B	31.140	8.205	3.795	0.000*
Group D					
Group C –	7.600	8.205	0.926	0.354	1.000
Group D					

Post hoc Dunn's test *shows p<0.05

Inference

The Post hoc Dunn's test showed that only the following pairs were Statistically significant.

Group B – Group C

Group B – Group D

Table 3: ARI scoring using chi square test

ARI Score (%)	Transbond (D) XT (A)	Transbond MIP (B)	Orthosolo (C)	Stedman Primer (D)
GRADE 0	0	12	8	16
GRADE 1	16	24	24	24
GRADE 2	64	44	68	56
GRADE 3	20	20	0	4

Chi square value – 16.919

Results

Statistical evaluation through Kruskal-Wallis test shows significant p value ($p<0.05$) indicating that the null hypothesis is rejected and there is difference among various groups with regard to Shear Bond Strength under dry and wet conditions which is shown in Table 1. From Table 1 and Fig.6, it can be concluded that the Mean Shear Bond Strength of Group B (Transbond MIP) under wet condition had the highest mean Shear Bond Strength of 12.24 MPa, followed by Group C (OrthoSolo) under salivary contaminated condition with the mean Shear Bond Strength of 9.23 MPa. The least mean Shear Bond Strength was found in Group D (Anabond Stedman) with 7.86 MPa. Fig. 7 shows the box plot chart, the distribution of values of SBS of different primers. Table 2 shows the correlation between individual groups through Post Hoc Dunn's Test. There was no significant difference between individual groups except between Group B (Transbond MIP) and Group D (Anabond Stedman) & Group B (Transbond MIP) and Group C (OrthoSolo) which showed statistically significant difference of $p<0.05$.

Chi Square test was performed for ARI scoring among the all groups and ARI scores were given in percentages in Table 3. Based on Chi square test, Group A(Transbond XT) showed grade 2 of about 64% and grade 3 of about 20% which indicated nearly 84% of teeth had more than 50% of adhesive present on the enamel surface. Group B (Transbond MIP) showed grade 2 of about 44% and grade 3 of about 20% which indicated nearly 64% of teeth had more than 50% of adhesive present on the enamel surface. Group C (OrthoSolo) showed grade 2 of about 68% and grade 3 of about 0% which indicated nearly 68% of teeth had more than 50% of adhesive present on the enamel surface. Group D (Anabond Stedman primer) showed grade 2 of about 56% and grade 3 of about 4% which indicated nearly 60% of teeth had more than 50% of adhesive present on the enamel surface. Grade 2 and 3 represent failure that occurred cohesively within bonding agent showing adequate bonding at junction of the enamel and bonding agents and also higher bond strength. Hence, the primers showed majority of bond failure at the adhesive bracket interface resulting in reduced enamel fracture with highest percentage exhibited by Transbond XT(84%) followed by OrthoSolo(68%), Transbond MIP(64%) and Anabond Stedman primer(60%). Group D (Anabond Stedman primer) exhibited grade 0 of about 16% followed by group B (Transbond MIP) of about 12%, Group C (OrthoSolo) of about 8% and group A (Transbond XT) of about 0%. This showed that Anabond Stedman primer displayed 16% of frequency of enamel fracture on debonding and indicating that the bond strength at the bracket adhesive interface is higher than that of at the enamel adhesive interface with no adhesive left on the tooth. Transbond XT primer showed 0% of frequency of enamel fracture indicating that no bond failure occurred at the adhesive bracket interface resulting in reduced enamel fracture. Fig. 8 shows the bar chart representation of the ARI scoring of all the groups and it was found to be significant $p<0.05$ indicating there is difference in ARI between groups.

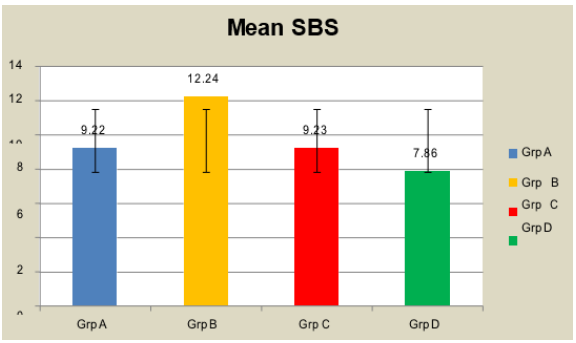

Figure 6: Showing bar chart representing Group B (Tranbond MIP – Tranbond XT) has the highest Shear Bond Strength among the various groups.

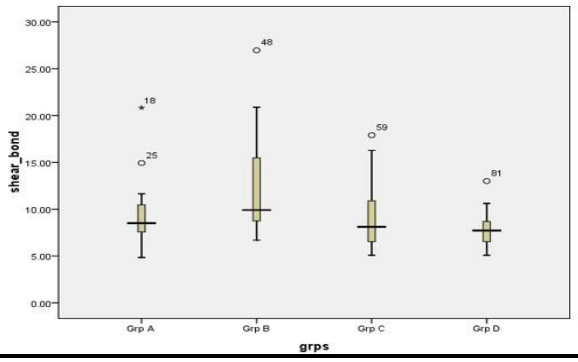

Figure 7 showing box plot chart, Group B (Transbond MIP – Transbond XT adhesive) shows the highest bond Strength followed by Group C, Group A, Group D in descending order.

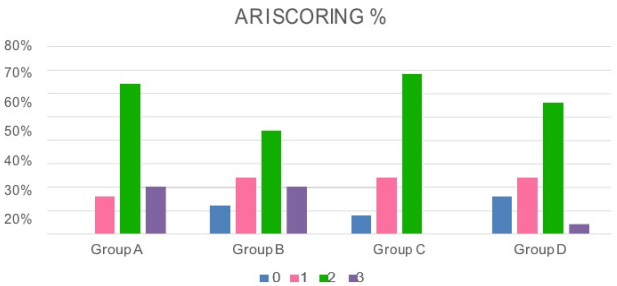

Figure 8: ARI scoring for groups A – D
P value – 0.0499* (Significant $p<0.05$)

Discussion

Although the direct bonding of orthodontic brackets has dramatically improved the clinical practice of orthodontics, tooth surface conditions and type of bonding material greatly affect bond strength. As per the earlier studies, clinically adequate Shear Bond Strength for a stainless steel bracket to enamel should be 6-8 MPa.[2] Debonding often results from failure in the bonding technique, low

retentiveness of bracket bases and masticatory forces. In an attempt to minimize these problems, the dental industry has incessantly developed hydrophilic bonding materials capable to withstanding the Orthodontic and masticatory forces.[9-10] Moisture contamination is another important problem, especially while bonding posterior teeth and in cases of surgically exposed teeth.[11] In order to achieve successful bonding to dentin, manufacturers have improved the hydrophilic properties of bonding materials. The introduction of these materials, which are less sensitive to wet conditions, should be useful for bracket bonding when moisture is present. Although traditional BISGMA resins are hydrophobic and are not efficient in a wet environment, MIPs have been used and found to offer comparable strength under both dry and wet conditions.[12]
Previous in vitro studies have used incisors for measuring Shear Bond Strength whereas canine, premolar, or molars have also been used for measurement of Shear Bond Strength. The use of premolars in the present investigation was followed by extensive review of literatures mentioning its use in the study conducted by McCourt et al.[13] which further supported their use in this study. In our study, statistical evaluation through Kruskal - Wallis test showed significant p value of about ($p<0.05$) which indicated that the null hypothesis is rejected and there is statistically significant difference among various groups with regard to Shear Bond Strength under dry and wet conditions The mean shear bond strength for the conventional composite Transbond XT with XT primer obtained from this study was 9.22 MPa, which was statistically significant and is in accordance with several studies of Meehan and Lalani et al.[14] found mean shear debond loads of 11.23 and 11.31 MPa. According to Reynolds,[2] 6-8 MPa was adequate for most clinical orthodontic needs. This bond strength was considered to be able to withstand masticatory and orthodontic forces. Various other studies with Transbond XT such as Cacciafesta V et al.[15] in 2003, Rajagopal et al.[16] in 2003, Schaneveldt and Foley[12] in 2002 and Grubisa et al in 2004[17] have reported bond strengths ranging from 10.4 MPa to 19.6 MPa under dry condition. Zeppieri IL et al.[18] (2003) observed higher bond strength in conventional Transbond XT primer of about 21.3 ± 6.8 MPa. However, there is large variations in the mean shear bond strength obtained from various studies which could be due to type of study whether invitro/invivo, sample size and type of collection, type of bracket used, curing, thermocycling and other methodologies used.

In our study, Transbond MIP (3M Unitek) showed highest mean shear bond strength of about 12.24 MPa followed by OrthoSolo primer (Ormco) and Anabond Stedman primer. This is because MIP contains 2-hydroxyethyl methacrylate (HEMA), polyalkenoate copolymers, ethanol along with carboxylate groups. This HEMA allows readily bonding to resin composite by lowering contact angle and an extension of the molecule (Newman et al.[19]) The Transbond MIP has ethanol, which is responsible for humidity tolerance and can enhance the adhesive strength when there is the minimal presence of sulcus fluid or moist breath.[20] Saliva contamination, however, covers the surface with not only considerable amounts of moisture but also substantial organic material. In addition to micromechanical retention, a reversible hydrolytic bond mechanism can be established by breaking or reforming of carboxylate salt complexes formed between the ionized carboxyl groups of methacrylate functionalized polyalkeonic acid copolymer and residual enamel calcium. This mechanism might enhance their performance under salivary contaminated conditions. Earlier studies[9,21] proved that there was no significant difference between Transbond XT primer and Transbond MIP in a dry environment. This finding agreed with reports by Webster et al.[10] and Grandhi et al.[11] but was in direct contrast to the findings of Littlewood et al.[9] in which the bond strengths of adhesive used with Transbond MIP were significantly lower than those with Transbond XT primer under dry conditions. However studies of Rajagopal et al.[16], Schaneveldt and Foley.[12] , proved that Transbond MIP showed promising results when used under moist conditions which is also proved with our study. Littlewood et al.[9] and Schaneveldt[12] study showed bond strengths found in MIP groups of about 14.02 MPa which is similar with our results whereas study by Grandhi et al.[11] showed the bond strength values of MIP primer and Transbond XT lower than our current study which should be expected because of bovine enamel used in his study. In our study, OrthoSolo primer showed shear bond strength of about 9.23 MPa under salivary contaminated conditions which was statistically significant.

In the present study on comparing the shear bond strength of the different groups with each other using post hoc Dunn's test, there was no significant difference between individual groups except between Group B (Transbond MIP) and Group D (Anabond Stedman) & Group B (Transbond MIP) and Group C (OrthoSolo) which showed statistically significant difference of $p<0.05$and the SBS of all groups exhibited higher values than the minimum orthodontic bracket bond strength as suggested by Reynolds[2] therefore, all could be considered sufficient for clinical application. This eliminates the need to maintain the teeth in a completely dry condition since all the hydrophilic primers provided acceptable shear bond strength. In this study, Transbond MIP showed higher shear bond strength and ability to resist bond failure and when compared to other primers. From the results and the observations of this study, we can say that Hydrophilic primers mainly Transbond MIP can be used in a situation where saliva contamination is expected to hinder the bonding procedures.

ARI is one of the most commonly used methods of assessing the quality of adhesion between the composite and tooth and also between bracket base and composite.[8] Various qualitative and quantitative methods have been used to determine the ARI on enamel surfaces or bracket bases after bracket removal, such as scanning electron microscopy (SEM), visual inspection,

photography, 3-dimensional profilometry, stereomicroscopy, and visual inspection with photography under magnification. In this study, The ARI scores were measured under Stereomicroscope with 10X magnification as they offer great possibilities for enamel or bracket-base surface investigation by providing high-quality results (Sorel O et al.[22]) Evaluation of ARI scores carried out half an hour to one hour after debonding showed that there was a statistically significant difference between conventional primer under salivary contaminated conditions and all other groups. Based on Chi square test, Group A (Transbond XT) showed grade 2 of about 64% and grade 3 of about 20% which indicated nearly 84% of teeth had more than 50% of adhesive present on the enamel surface. Group B (Transbond MIP) showed grade 2 of about 44% and grade 3 of about 20% which indicated nearly 64% of teeth had more than 50% of adhesive present on the enamel surface. Group C (OrthoSolo) showed grade 2 of about 68% and grade 3 of about 0% which indicated nearly 68% of teeth had more than 50% of adhesive present on the enamel surface. Group D (Anabond Stedman primer) showed grade 2 of about 56% and grade 3 of about 4% which indicated nearly 60% of teeth had more than 50% of adhesive present on the enamel surface. Grade 2 and 3 represent failure that occurred cohesively within bonding agent showing adequate bonding at junction of the enamel and bonding agents and also higher bond strength. Hence, the primers showed majority of bond failure at the adhesive bracket interface resulting in reduced enamel fracture with highest percentage exhibited by Transbond XT(84%) followed by OrthoSolo(68%), Transbond MIP(64%) and Anabond Stedman primer (60%). This is in accordance with the study by Jou et al.[23] for light-cured adhesives that 70% of the failures occurred at the adhesive- bracket interface.

Bishara, et al.[24] in 1999 stated that when the failure occurs at the enamel/adhesive interface there is an increased risk of enamel fracture. However, if the failure occurs in the interface adhesive/bracket, the enamel is often preserved. In our study, ARI scores were graded predominantly with 2 and 3 grades for all the primer groups which showed very less risk of enamel integrity. Group D (Anabond Stedman primer) exhibited grade 0 of about 16% followed by group B (Transbond MIP) of about 12%, Group C (OrthoSolo) of about 8% and group A (Transbond XT) of about 0%. This showed that Anabond Stedman primer displayed 16% of frequency of enamel fracture on debonding and indicating that the bond strength at the bracket adhesive interface is higher than that of at the enamel adhesive interface with no adhesive left on the tooth. Transbond XT primer showed 0% of frequency of enamel fracture indicating that no bond failure occurred at the adhesive bracket interface resulting in reduced enamel fracture.[7]

All primers performed well under appropriate dry or salivary contaminated condition suggesting that all are suitable for clinical application However, the limitation of the present study is that it is an in vitro study so that forces like masticatory and occlusal stress seen in clinical situations could not be simulated. In vitro studies provide very important data concerning the physical and mechanical properties of a material, but the final evaluation can only be provided when the efficiency of these materials are assessed under clinical conditions. Hence, it is necessary to assess the bond strength of various hydrophilic primers clinically.

Conclusion

From this study, following conclusions are made:

1. Based on p value, all the primers are highly statistically significant in achieving the acceptable shear bond strength.
2. Under contaminated condition, Transbond MIP (3M Unitek) showed highest mean shear bond strength of about 12.24 MPa followed by OrthoSolo primer (Ormco) and the lowest shear bond strength by Anabond Stedman primer. Transbond XT showed mean shear bond strength of 9.22 MPa under dry condition.
3. Based on Post hoc dunn's Test, there was no significant difference between individual groups except between Group B (Transbond MIP) and Group D (Anabond Stedman) & Group B (Transbond MIP) and Group C (OrthoSolo) which showed statistically significant difference of $p<0.05$.
4. The primers showed majority of bond failure at the adhesive bracket interface resulting in reduced enamel fracture with highest percentage exhibited by Transbond XT(84%) followed by OrthoSolo(68%), Transbond MIP(64%) and Anabond Stedman primer(60%).
5. Transbond XT primer showed 0% of frequency of enamel fracture indicating that no bond failure occurred at the adhesive bracket interface resulting in reduced enamel fracture.

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None.

Conflict of Interest

None.

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