EVALUATION OF SHEAR BOND STRENGTH OF ORTHODONTIC STAINLESS STEEL BRACKETS WITH SEP (SELF-ETCH PRIMER) AND MIP (MOISTURE-INSENSITIVE PRIMER) - AN IN VITRO STUDY

Authors:
Dr. V.D. Swami, MDS
Reader,
Dept of Orthodontics & Dentofacial Orthopedics
Bharati Vidyapeeth Dental College & Hospital,
Pune - 411 043
Email: drvinitswami@gmail.com
Phone no.: 020-24373266

Dr. S.V. Deshmukh, MDS, MOrth RCS(Edi)
Diplomate Indian Board of Orthodontics
Professor,
Dept of Orthodontics & Dentofacial Orthopedics
Bharati Vidyapeeth Dental College & Hospital, Pune

Dr R.B. Sable, MDS, MOrth RCS(Edi)
Diplomate Indian Board of Orthodontics
Professor and Head
Dept of Orthodontics & Dentofacial Orthopedics
Bharati Vidyapeeth Dental College & Hospital, Pune

Abstract
Bonding is one of the keystone procedures in fixed appliance treatment. Bonding includes various steps like, Cleaning, Polishing, Etching, Drying, Isolation of tooth. Any mistake or avoidance in any step will affect the shear bond strength. This study was conducted to measure and compare the shear bond strength of orthodontic stainless steel brackets bonded to enamel both in dry and wet (artificial saliva) environment with Transbond XT 3M Unitek conventional primer, Self-etch primer (SEP) and Moisture-insensitive primer (MIP) with an eye on judging the effectiveness of these new materials as well as reducing the chair side time of the clinician and comfort to the patient.

The study showed significant difference in shear bond strength in dry and wet medium. In dry field Conventional Transbond Primer XT showed the highest mean shear bond strength of 14.02 ±1.06 MPa. Transbond SEP showed a mean shear bond strength of 13.09±2.97 MPa. and Transbond MIP showed slightly lower mean bond strength (9.56 ±1.06MPa).

In wet field Conventional Transbond Primer XT showed low mean shear bond strength of 3.69 ±1.62 MPa. Transbond Self-etch Primer showed a mean shear bond strength of 8.68±2.87MPa and Transbond Moisture insensitive primer (MIP- S1) showed mean shear bond strength of 7.48±0.83MPa while MIP-S2 showed mean shear bond strength of 3.00±1.00 MPa.

Key Words
Bonding, Self-etch primer, Moisture insensitive primer

INTRODUCTION
In early 1900s, the only practical way of placing a fixed attachment onto a tooth was by using a band that could be cemented to the tooth. The introduction of acid etch bonding technique by Buonocore in 1955, brought the concept of bonding various resins to enamel. In orthodontics, the use was very much appreciated and banding of the fixed appliances was immediately replaced by bonding of brackets directly to the tooth. Newman (1965) was the first person who used epoxy resin for bonding stainless steel brackets to enamel. This development resulted in improvements in
orthodontic treatment. Any adhesive system in use should be self-limiting, economical, and easy to bond. It should combine maximum bond strength with minimal risk of damage to enamel. In addition, the bond strength between enamel and the orthodontic bracket depends on various factors including the type of enamel conditioners, acid concentrations, length of etching time, the bonding agent (primer), the composition of the adhesive, the bracket material, bracket base design, the oral environment as well as the skill of the clinician. Many times bond failures result due to moisture contamination. In such situations maximum bond strength is needed to compensate for the unfavorable moist environment in which the polymer adhesive system operates.

Recently, various developments in dental material sciences have led to improvement in adhesive bonding formulations, resulting in the current availability of a wide range of products including self-etch primer solutions and moisture insensitive primers.

Self-etching primers (SEP) are often referred to as sixth generation bonding agents. SEP usually contains methacrylated phosphoric acid esters, formed when phosphoric acid and a methacrylate group are combined into a molecule that etches and primers the tooth surface simultaneously. Thus such adhesive systems reduce the number of procedural steps during bonding, decrease the technique sensitivity and chair side time without compromising the outcome.  

Recently, a new self-etch primer, one-up Bond F (USA Inc, Irvine, Calif) that contains and releases fluoride ions has been also introduced.

It would be advantageous to be able to bond the enamel in wet environment particularly in areas such as second molars and partially erupted teeth.

During recent years, manufacturers have sought to enhance the performance of the bonding system in the presence of moisture by introducing a novel material like Moisture Insensitive Primer (MIP).

MIP is hydrophilic and contains mainly 2-hydroxyethylmethacrylate, polyalkenoate copolymers with carboxylate groups and ethanol. This primer is generally known to provide adequate bond strength in wet environment when used with light activated resin.

All these exciting developments have stimulated research to evaluate the efficacy of the newly introduced adhesive bonding products like self-etch primer (SEP) and moisture insensitive primer (MIP) on shear bond strength of orthodontic stainless steel brackets and their utility in day to day orthodontic practice.

**Aims and Objectives**

To measure and compare the shear bond strength of orthodontic stainless steel brackets bonded to enamel both in dry and wet (artificial saliva) environment using:

1. Conventional primer along with light activated composite resin.
2. Self-etch primer (SEP) along with light activated composite resin.
3. Moisture-insensitive primer (MIP) along with light activated composite resin.

Self-etch primer and Moisture-insensitive primer are trying to replace primers in routine orthodontic practice. This study was conducted with an eye on judging the effectiveness of these new materials in reducing the chair side time of the clinician as well as the patient. The objectives of this study were directly to compare the effective shear bond strengths of self-etch primer and moisture-insensitive primer over conventional primer and indirectly the cost, benefit and risk ratio of these materials in day to day orthodontic practice.

**Materials and Methods**

The study was conducted at the Department of Orthodontics and Dentofacial Orthopedics, Bharati Vidyapeeth University Dental College and Hospital and ARAI (Automotive Research Association of India) Pune.

105 extracted premolar teeth were used in this study. All the teeth selected had intact buccal enamel surfaces with no cracks, caries or developmental defects and were stored in distilled water at room temperature.

Customized square metal block of 3.5x3.5 cm was prepared so that all the teeth could be mounted in a square block of green stone plaster. Before bonding the stainless steel brackets on the tooth, the buccal surface of each tooth was cleaned and then polished using a rubber cup dipped in pumice slurry free of fluoride. Then the buccal surface was thoroughly rinsed with water and dried with oil free air spray. Orthodontic Lewis stainless steel brackets with a mesh base were used for this study. (Alexander 0.018 slot prescription; American Orthodontic Co.) After bonding, all the teeth were stored in distilled water at room temperature.

The teeth were divided into 7 groups of 15 teeth each. Three primer systems were used namely conventional (Transbond XT), self-etch primer (TransbondPlus SEP)
and moisture-insensitive primer (Transbond MIP) (fig 1)

Group I) Conventional primers in dry environment
Control group) The buccal surfaces of the teeth were etched with 37% phosphoric acid gel for 15 seconds, washed thoroughly with water and dried. Conventional primer (Transbond XT 3M Unitek) was applied to the enamel surface. Adhesive paste (Transbond XT 3M Unitek composite resin) was placed on the base of the brackets and brackets were bonded on the enamel with gentle pressure. The excess material was removed with an explorer. The adhesive was light cured on all 4 sides of the bracket for 10 seconds.

Group II Self-Etch Primer in dry environment
Transbond plus self etch primer was gently rubbed on the enamel for 3 seconds with a disposable applicator brush and gently evaporated with air. The brackets were bonded with Transbond XT (3M Unitek) adhesive paste and light cured on all 4 sides for 10 seconds each.

Group III) Moisture insensitive primer (MIP) in dry environment
Enamel surface was etched with 37% phosphoric acid gel (3M Unitek) for 15 seconds, rinsed and dried. Moisture insensitive primer (MIP) was applied to enamel surface and brackets were bonded with adhesive paste (3M Unitek Transbond XT). The adhesive was light cured on all 4 sides of the bracket or 10 seconds each.

Group IV) Conventional primer in wet condition
The buccal surfaces of teeth were etched with 37% phosphoric acid gel for 15 seconds following thorough insing and drying. Then conventional primer Transbond XT (3M Unitek) was applied to enamel surface and light cured for 10 seconds. A thin coat of artificial saliva (Wet mouth) was applied with brush tip (Figure XII). The brackets were bonded with Transbond XT (3M Unitek) adhesive paste and light cured on all four sides for 10 seconds each.

Group V) Self etch Primer in wet condition
Enamel surface was simultaneously etched and primed with Transbond self etch primer (3M Unitek) for 3 seconds with a disposable applicator and then gently evaporated with oil free air. Tooth was moistened with thin coat of artificial saliva with the help of brush tip. The tooth was reprimed with Transbond SEP as previously applied. Brackets were bonded similar to control group and light cured on all four sides for 10 seconds each.

Group VI) Moisture insensitive primer under wet environment S1:
Enamel surface was etched, rinsed and dried. A thin coat of MIP was applied and gently evaporated with air. The tooth was moistened with a thin coat of artificial saliva. Tooth was reprimed with another coat of MIP and later brackets were bonded with Transbond XT adhesive paste and light cured on all 4 sides for 10 seconds each.

Group VII) Moisture insensitive primer under wet environment S2:
In this group, after etching procedure, a thin coat of artificial saliva was applied on the enamel surface. Moisture insensitive primer was applied, gently evaporated and then the brackets were bonded with Transbond XT (3M Unitek) adhesive paste and cured on all 4 sides for 10 seconds each.

After bonding, all the samples were stored in distilled water at room temperature and bond strength was tested after 7 days.

Measuring the shear bond strength:
Instron testing machine Model 5502 (Figure 2) was used to measure the shear bond strength. The cross head of

Fig. 1 Primers - Transbond XT SEP MIP

Fig. 2 Instron testing machine
the testing machine moved at a speed of 5mm / min until the bracket sheared (Figure 3). None of the teeth showed enamel fracture on debonding after testing under Instron testing machine. Shear bond strength was recorded in Mega Pascal’s (Mpa).

![Fig.3 Testing shear bond strength](image)

**Result and Discussion**

In the first 3 groups, the bonding was done in dry field using conventional primer, self-etch primer and moisture insensitive primer. The conventional primer group was considered as the control group.

In the other 4 groups bonding was done in wet field using the same primers (conventional, SEP, MIP). Again the conventional primer group was used as the control group.

The VI and VII group where MIP was used as the bonding agent, the procedure of bonding differed in the manner in which contamination was conducted. In the VIth group, the contamination was carried out after primer application while in the VIIth group contamination was done before application of the primer.

After measuring the shear bond strength for all 7 groups, the mean bond strength was calculated for each group in dry and wet fields. Table I shows mean bond strength, standard deviation and range for each group.

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>BOND STRENGTH (MPa)</th>
<th>MEAN</th>
<th>SD</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ETCH,DRY,XT (control)</td>
<td></td>
<td>14.02</td>
<td>1.06</td>
<td>12.6-15.45</td>
</tr>
<tr>
<td>2 DRY,SEP</td>
<td></td>
<td>13.09</td>
<td>2.97</td>
<td>6.4-19.0</td>
</tr>
<tr>
<td>3 ETCH, DRY,MIP</td>
<td></td>
<td>9.56</td>
<td>1.06</td>
<td>8.0-11.2</td>
</tr>
<tr>
<td>4 ETCH, XT, WET</td>
<td></td>
<td>3.69</td>
<td>1.06</td>
<td>1.5-5.5</td>
</tr>
<tr>
<td>5 DRY,SEP,WET,SEP</td>
<td></td>
<td>8.65</td>
<td>2.87</td>
<td>2.8-12.2</td>
</tr>
<tr>
<td>6 ETCH,DRY,MIP,WET,MIP- S1</td>
<td></td>
<td>7.48</td>
<td>0.8</td>
<td>5.6-8.4</td>
</tr>
<tr>
<td>7 ETCH, DRY,WET,MIP- S2</td>
<td></td>
<td>3.00</td>
<td>1.00</td>
<td>0.7-5.28</td>
</tr>
</tbody>
</table>

From the above table the following results were obtained:-

In Dry Field: Conventional Transbond primer XT (Group I ‘control’) showed the highest mean shear bond strength of 14.02 ±1.06 MPa. Transbond Self-etch Primer (Group II) showed a mean shear bond strength of 13.09 ±2.97 MPa. Transbond Moisture insensitive primer (Group III) showed slightly lower mean bond strength (9.56 ±1.06MPa) than the other two groups. The above bond strength values indicate that all three primers provide an adequate bond strength in dry conditions. The conventional primer amongst the three seems to be the best with regards to the bond strength when used in dry environment.

In Wet Field: Conventional Transbond primer XT (Group IV ‘control’) showed a significantly low mean shear bond strength of 3.69 ±1.62 MPa. Transbond Self-etch Primer (Group V) shows mean shear bond strength of 8.68±2.87MPa. Transbond Moisture insensitive primer (MIP- S1 Group VI) showed mean shear bond strength of 7.48±0.83MPa. Transbond Moisture insensitive primer (MIP- S2 Group VII) showed mean shear bond strength of 3.00±1.00 MPa.

The above values on observation indicates that SEP and MIP were effective bonding agents in wet field, though MIP is not clinically reliable if moisture contamination occurs before application of the primer.
This in effect may limit the use of MIP. The means for the various groups were then subjected to unpaired t-test and analysis of variance (ANOVA), for comparison of their shear bond strength.

Table II shows a comparison between mean shear bond strengths of orthodontic stainless steel brackets bonded with conventional primer, SEP and MIP.

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>Primers Used</th>
<th>Mean Bond Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dry field</td>
</tr>
<tr>
<td>I and IV</td>
<td>Transbond XT</td>
<td>14.02±1.06</td>
</tr>
<tr>
<td>II and V</td>
<td>Transbond Plus SEP</td>
<td>13.09±2.97</td>
</tr>
<tr>
<td>III and VI</td>
<td>Transbond MIP S1</td>
<td>9.56±1.06</td>
</tr>
<tr>
<td>III and VII</td>
<td>Transbond MIP S2</td>
<td>9.56±1.06</td>
</tr>
</tbody>
</table>

All the values after comparison by ANOVA statistical analysis indicate that mean shear bond strengths observed in all the 7 groups were statistically significant (p=0.0000).

From the above results, it is seen that the mean shear bond strengths in dry field, using different primers, were higher than the clinically acceptable limit of bond strength, which is proposed to be in the range of 6-8 MPa as recommended by Reynolds.

The results showed that the highest mean shear bond strength of 14.0 ± 0.95 MPa was achieved with Transbond XT adhesive when it was used with conventional hydrophobic primer Transbond XT.

These findings indicate that Transbond XT adhesive provides stronger bond with Transbond XT Primer than self -etch primer(SEP) and moisture-insensitive primer(MIP) in dry field. This result were comparable to Littlewood et al’s observation where hydrophilic primer showed significantly lower bond strength than conventional hydrophobic primer. The results also showed that SEP had adequate shear bond strength in dry field with reduction of steps of bonding procedure. The results of the study corroborates with the findings of Perdigao and Lopes and Helen Grubisa and Don Raboud whose studies also showed that self-etch primer had clinically acceptable shear bond strength when compared with conventional primer in dry field.

The present findings were also similar to Peutzfeldt A. Nielsen LA where there was little difference observed in the bond strength between phosphoric acid etch and self-etch adhesive group in dry field.

Samir Bishara, Gordan stated that use of acidic primers to bond orthodontic stainless steel brackets could provide clinically acceptable bond strength (10.4±4.4 MPa). This study also demonstrates results in a similar vein. The mean shear bond strength of MIP measured in the study was comparable to that measured by Ram Grandhi, EC Combe in the dry field.

The present study showed that the mean shear bond strength when conventional primer was used, was more than the mean shear bond strength when MIP is used in dry conditions. SEP showed slightly higher mean shear bond strength of 13.0 ± 2.97 MPa as compared to MIP 9.56±1.06 MPa in dry field. These results contradict the findings of Zeppieri II, Chung CH et al’ and Bishara et al” who found that MIP had a higher shear bond strength of 20.7±0.5MPa in dry field. However the mean shear bond strength of SEP in dry field in our study was comparable to Zeppieri II, Chung CH et al’ and Bishara et al” The study showed the mean shear bond strength of SEP in wet environment as 8.65±2.87 MPa which was adequate and clinically acceptable as recommended by Reynolds’. These findings were similar to Zeppieri II, Chung CH et al’ where they stated that saliva contamination did not affect the bond strength of SEP when SEP was reapplied. The present study showed no significant difference between SEP and MIP mean bond strengths in wet field when contamination occurs after application of primer and if the primers were reapplied after contamination.

Conventional primer showed significantly low mean shear bond strength (3.59±1.62MPa) in wet field which was similar to that observed by Cacciafesta V, Storidinni MF et al’. Webster MJ, Nanda RS measured the shear bond strength of orthodontic stainless steel brackets in which moisture contamination occurs after MIP application and when enamel surface was reprimed. All of them showed shear bond strength which was adequate and clinically acceptable.
Comparison of Transbond XT, SEP and MIP in dry field

Comparison of Transbond XT, SEP and MIP in wet field
MIP-S1 group where saliva contamination was done after application of primer followed by repriming of the enamel surface, the mean shear bond strength was 7.48±0.8 MPa which was higher than MIP-S2 where contamination was introduced before application of primer (3.00±1.00 MPa). Rajagopal R, Padmanabhan S\textsuperscript{10}, Hobson RS, Ledvinka J et al \textsuperscript{11} also showed comparable mean shear bond strength when the enamel was reprimed after moisture contamination.

Thus, the results indicates that SEP and MIP both perform significantly well in dry and moisture contaminated fields, though MIP does not perform well if it is not reapplied after contamination.

Taking into consideration the above results and discussion, the use of SEP seems to be less technique sensitive. SEP will definitely reduce chair side time as it etches and primes simultaneously and thus may offer a better alternative to bonding with conventional primer, as it would reduce the bonding steps and thus be more comfortable to the patient. However, the use of SEP is limited to a single patient and therefore would be more expensive.

MIP would be a better alternative when isolation is difficult, as may occur in conditions of impacted canines and second molars. This is because MIP is more cost effective in comparison to SEP and shows comparable bond strength to SEP in wet environment.

Limitation of the study:
This was an in vitro study; hence it is necessary to compare the results with those that might be obtained in the oral environment. Also SEM studies would give us a clearer picture of the structure of the enamel surface when SEP and MIP are used as primers for bonding purposes. Reiko Y, Kasai k \textsuperscript{16} has stated in their SEM study that SEP causes less dissolution of enamel surface.

In addition, more research is needed to determine the shear bond strength achieved with these new primers in the first 30 minutes to simulate the time the initial archwires are tied. One of the advantages of the study was that human premolar teeth were used. Hence the findings may be more appreciable and authentic.

Conclusion
• Brackets bonded with Transbond XT primer and Transbond Plus Self-etch primer show the highest mean shear bond strength of 14.02±1.06 MPa and 13.09±2.97MPa respectively in dry field.
• Transbond MIP also shows effective mean shear bond strength of 9.56±1.06MPa in dry field.
• The conventional primer shows significantly low mean shear bond strength of 3.69±1.62MPa in wet medium.
• SEP shows mean shear bond strength of 8.65±2.87MPa and MIP shows 7.48±0.8MPa (after primer application) and 3.00±1.00MPa (before primer application) mean shear bond strength in moist conditions. Bond strength of self-etch primer although affected by salivary contamination, provides clinically acceptable shear bond strength. Also, since SEP is a one step procedure, it is less technique sensitive.
• Moisture insensitive primer also shows effective shear bond strength in contaminated field provided it is reapplied. So it is more technique sensitive. Thus the results show SEP and MIP have a potential to produce effective bond strength in dry as well as contaminated fields.

Summary
Achieving effective and lasting shear bond strength between enamel, adhesive components and orthodontic brackets is essential in day to day orthodontic practice. The use of bonding techniques i.e. direct as well as indirect has expanded significantly during the last few decades. New materials and techniques are modifying many conventional approaches in recent times. The effectiveness of direct bonding in achieving a mechanical bond of conventional composite resin to enamel, requires a dry environment. Any contamination during bonding procedure reduces the bond strength completely and is considered the most common reason for bond failure. Also conventional bonding technique requires number of steps including etching, priming and curing. To overcome such problems, new materials like self etch primers and moisture insensitive primers have been introduced. The study showed that self-etch primer produces clinically acceptable shear bond strength in dry as well as moist environment. Thus it reduces the bonding steps by etching and priming simultaneously and saves the clinician’s time by making the job simpler. Also it was observed that self-etch primer is less technique sensitive, requires less chair side time and thus increases comfort of the patient.

Moisture insensitive primer also showed effective shear bond strength in dry as well as wet field. The bond strength was adequate when moisture contamination occurred after primer application.
Results of the study states that SEP and MIP both perform equally in dry and wet mediums. The only limitation of SEP in comparison with MIP is the cost effectiveness.

References:


