Original Article

An evaluation and comparison of the shear bond strength of two newly formulated primer systems with a conventional primer system under different conditions: An *in vitro* study

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Abstract

Aims and Objectives: This study was carried to evaluate the shear bond strength of brackets bonded with self-etching primer and moisture insensitive primer (MIP) and compare it with the conventional adhesive system. **Materials and Methods:** A total of 90 extracted human premolar teeth were selected and divided into three groups of 30 teeth each with two sub groups (dry and wet), of 15 teeth each. Each group was bonded with three different types of bonding systems namely visible light cure Clearfil Liner Bond 2V, MIP and Transbond XT. These groups were named SD, MD and CD in dry conditions and SW, MW and CW in wet condition and each of these groups were color coded. The shear bond strength of the bonding system in each group was tested using Universal testing machine Instron (Instron model:4206, Instron Corporation, USA). **Results:** In dry condition all three groups showed good bond strength. Self-etch primer showed the average highest bond strength, followed by Transbond XT and then MIP. In wet condition MIP has highest bond strength, followed by self-etching primer and Transbond XT. **Conclusion:** Under dry conditions conventional primer is the material of choice. Under wet conditions, MIP showed the highest bond strength and hence can be considered to be a material of choice.

Key words: Conventional primer, moisture insensitive primer, self-etch primer, shear bond strength

INTRODUCTION

Bonding systems are one of the most researched fields in dentistry. In orthodontics too, bonding systems have seen a continuous innovation with latest entrants being moisture insensitive primer (MIP) and self-etching primer, which have claimed to be a blessing to orthodontists, while bonding in wet conditions.[1]

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Rapid strides in material science over the years produced the conventional two paste system, which provided good bond strength in dry conditions, but bond strength is wet conditions was unreliable and bonding procedure was time consuming challenging offer to the orthodontist.[2,3] Bonding is a technique sensitive procedure and moisture is cited as most common cause of bond failure.[4,5] Contamination causes plugging of porosities caused by acid etching and a reduction is surface energy, penetration of resin is impaired and the micromechanical retention is compromised. Despite the hydroxyl groups, conventional Bis phenol A glycidal methacrylate resins are hydrophobic and are efficient only in dry environment.[5,6] A possible solution to this problem has been offered by the development of MIP. These are developed based on dentin bonding agent, which have hydrophilic component,

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such as hydroxyl ethyl methacrylate (HEMA) and maleic acid dissolved in acetone, that are efficient even in the presence of moisture.[7,8] Another novel concept is the sixth generation bonding systems, where etching and priming agents are combined into a single acidic primer solution. These self-etch primers help the clinician save time, reduce cross contamination and reduce wastage. Because they are hydrophilic, it is logical that they may be efficient in situations with minimal moisture contamination.[9] This study was undertaken to evaluate the mean shear bond strength values of self-etching primer system and MIP system and compare the mean shear bond strength values of both these materials to conventional light cure adhesive system under dry and wet conditions.

Aims and objectives

The aims and objectives of this study is a comparative evaluation of the new primer combination with conventional acid etchant with regard to shear bond strength in dry and wet conditions.

MATERIALS AND METHODS

A total of 90 human premolar teeth extracted for the orthodontic purpose were selected and stored in a solution of 0.1% (wt/vol) thymol to prevent dehydration and bacterial growth.

Inclusion criteria's

Criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents (e.g., H_2O_2), with no cracks and no caries.

The teeth were fixed in a self-cure acrylic block such that the roots were completely embedded in the acrylic up to cemento enamel junction. The blocks were color coded for easy identification [Figure 1] and the samples were then segregated into six groups of 15 samples each:

Groups bonded without salivary contamination (dry series). SD, MD, and CD.

Groups bonded with salivary contamination (wet series). SW, MW and CW.

Bondable stainless steel 0.022 slot Preadjusted Edgewise Appliances (PEA) (Roth prescription) premolar brackets (American Orthodontics, U.S.A) were used. The average bracket base area was determined to be 8.686 mm^2 (as prescribed by the manufacturer).

QHL 75TM Curing Light Dentsply, with an intensity of 480 nm was used for polymerization. 37% phosphoric acid was used as an etchant for conventional Transbond XT primer (3M Unitek, USA) and MIP. Transbond XT was used as an adhesive for bonding in all six groups.

Three types of primers were used in this study under both dry and wet field [Table 1].

1. Conventional: Transbond XT primer.
2. MIP: Transbond MIP is a hydrophilic material that allows bonding to a moist environment without compromising bond strength.

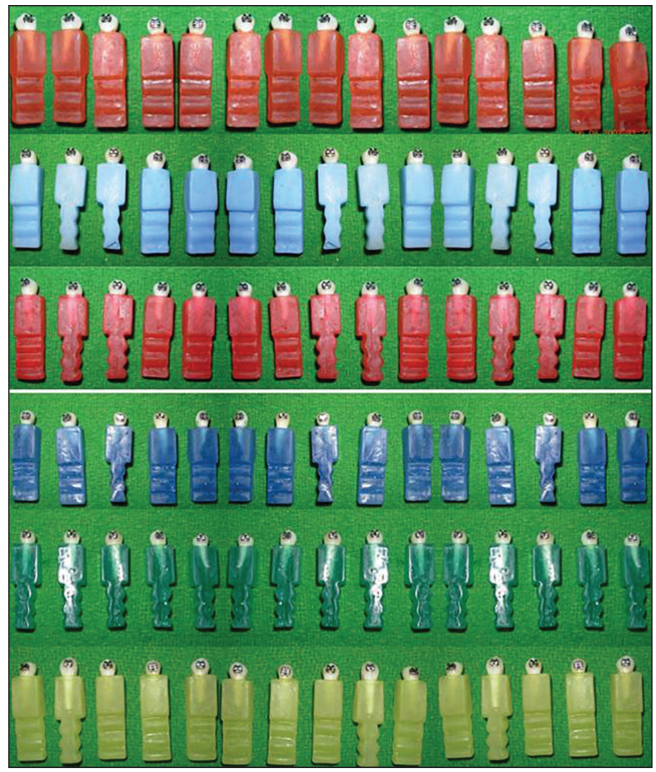


Figure 1: 90 extracted human premolar teeth bonded with three different types of bonding systems; visible light cure Clearfil Liner Bond 2V, Moisture Insensitive primer and Transbond XT

Table 1: Types of primers were used in this study under both dry and wet field

Group	Number of teeth	Colour	Primer
SD	15	Orange	Clearfil Liner Bond 2V, self-etching primer (dry condition)
MD	15	Navy blue	Moisture insensitive primer (dry condition)
CD	15	Red	Conventional primer-Transbond XT (dry condition)
SW	15	Blue	Clearfil Liner Bond 2V, self-etching primer (wet condition)
MW	15	Green	Moisture Insensitive Primer (Wet condition)
CW	15	Yellow	Conventional primer-transbond XT (wet condition)

3. Self-etching primer: Clearfil Liner Bond 2V (Kuraray, Co, Ltd, Osaka, Japan) is also a hydrophilic primer that can be used under both dry and wet conditions.

The shear bond strength of the bonded teeth was determined using Instron testing machine model 4206 at the National Institute of Technology, Karnataka, Surathkal [Figure 2]. The crosshead speed of the machine was 1 mm/min.

Natural saliva was collected from the operator within an hour after brushing, without any food-consumed in-between.

Bonding procedure

Bonding samples in group SD

The buccal surface of all the samples in the group were pumiced and thoroughly rinsed with distilled water. The tooth surfaces were dried and isolated to avoid contamination of the treatment area. Equal amounts of primer liquids A and B were dispensed into the mixing dish and mixed immediately before application. The mixture was applied to the buccal surface and the bracket base with a disposable brush tip and it was left for 30 s.

After conditioning the tooth surface for 30 s, oil free air stream was applied to evaporate the volatile ingredients. The necessary amount of bond liquid A was dispensed into the mixing dish. Bond liquid A, was applied to the buccal surface and the bracket base with a disposable brush tip. After application the bond film was made as uniform as possible using a gentle oil free air stream. The bracket was placed on the tooth surface gently, but firmly pressed in place and was light cured for 20 s with the visible light-curing unit.

Bonding samples in group MD

The buccal surface of the premolar teeth were etched with 37% phosphoric acid for 15 s washed with water for 10 s,

Figure 2: Universal testing machine (Instron 4206 USA), National Institute of Technology, Surathkal, Karnataka

and dried with three-way syringe for 10 s. Three drops of MIP was taken and coated on the entire etched surface of the teeth. A gentle airburst was directed perpendicular to the labial surface for 2-5 s and then the brackets were bonded with Transbond XT adhesive and light cured for 40 s.

Bonding samples in groups CD

The teeth were etched with 37% phosphoric acid for 15 s and dried with three-way syringe for 10 s. Transbond XT primer was applied to the etched enamel surface, and then the brackets were bonded with Transbond XT and light cured for 40 s.

Bonding samples in groups SW

After the teeth in the sample are pumiced and thoroughly rinsed with distilled water, the tooth surface was dried. Self-etching primer was rubbed on to the enamel surface for 3 s and after 15 s oil free air was blown to gently evaporate the excess. After 2 min two coats of saliva was applied and blotted with gauze leaving the surface moist. Then again self-etch primer was re etched on the wet enamel for 3 s and after 15 s oil free air was blown to gently evaporate the excess, and then the brackets were bonded as in group SD.

Bonding samples in groups MW

The teeth was etched with 37% phosphoric acid for 15 s and washed with water for 10 s and dried with three-way syringe for 10 s. Two coats of saliva were applied to the etched surface and excess was blotted with gauze leaving the surface moist. Three drops of MIP was taken and one labial coat of MIP was applied covering the etched surface using a brush. Oil free air was blown for 2-5 s aimed perpendicular to labial surface, and then the brackets were bonded as in group MD.

Bonding samples in groups CW

The premolar teeth were etched with 37% phosphoric acid for 15 s washed with three-way syringe for 10 s. Two coats of saliva was applied to the etched surface, excess saliva was blotted with gauze leaving the surface moist. Transbond XT primer was applied and then the brackets were bonded as in group CD.

The bonded specimens were stored in distilled water at room temperature for 24 h before testing. The shear bond strength of the bonded, stored specimens were tested after 24 h of bonding in an Instron testing machine model 4206 with a crosshead speed adjusted to 1 mm/min.

The acrylic block mounted with the specimen was secured to the lower grip of the machine (fixed head) and a custom made blade was fixed in the upper grip (movable head) connected to the load level the blade was positioned in such a way that it touched the bracket [Figure 3].

The crosshead speed was adjusted to 1 mm/min and the force at which the bracket debonded was recorded. The bond strength was calculated in Megapascals by using the following formula.

$$\text{Force in Newton} = \frac{\text{Bond strength MPa}}{\text{Surface area of the bracket in mm}^2}$$

Adhesive remnant index

Any adhesive remaining after debonding was assessed under × 10 magnification according to adhesive remnant index (ARI) graded as per Artun and Bergland[10] index and scored with respect to the amount of resin material adhering to the enamel surface.

The scale used has a range between 5 and 1, 5-no composite remained on the enamel; 4-<10% of composite remained on tooth surface; 3->10% but <90% of composite remained on tooth surface; 2->90% of composite remained on tooth surface and 1-all the composite remained on tooth surface, along with impression of the bracket base.

RESULTS

Statistical analysis

Then following analysis were employed to statistically evaluate the results:

1. Student's *t*-test
2. ANOVA
3. Chi-square test
    - In dry condition all three groups showed good bond strength. Self-etch primer showed the average highest bond strength followed by Transbond XT, and then MIP [Figure 4].
    - In wet condition MIP has highest bond strength followed by self-etch and Transbond XT [Figure 5].
    - In inter group comparison between dry and wet condition states that [Table 2]:
        a. There was statistically significant reduction in bond strength of self-etch primer between dry and wet state [Graphs 1 and 2].
        b. There was no statistically significant reduction in bond strength of MIP in dry and wet state.
        c. There was very high significant difference in bond strength of Transbond XT in dry and wet state. The bond strength greatly reduced in wet state and was below the ideal clinical bond strength.

The differences in ARI scores noted were statistically significant.

DISCUSSION

In self-etching primers, the reactive components are esters from bivalent alcohols with methacrylic acid and phosphoric acid or its derivatives. The phosphate residue is thought to etch the enamel, while the methacrylate component of the molecule is available for co-polymerization with the bonding agent and composite resin. With this process, there is no need to rinse off reaction products or residual phosphoric acid esters because both are subsequently polymerized into the bonding layer.[1]

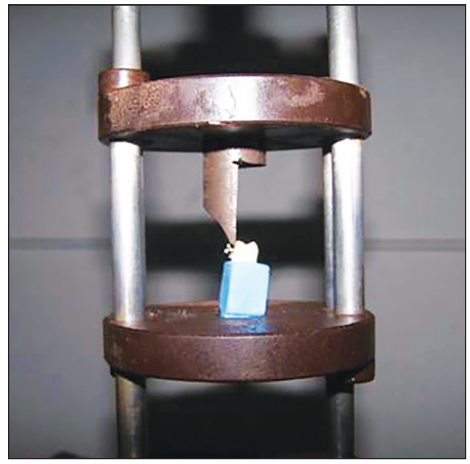


Figure 3: Acrylic block mounted with the specimen was secured to the lower grip of the machine (fixed head) and a custom made blade was fixed in the upper grip (movable head) connected to the load level the blade was positioned in such a way that it touched the bracket

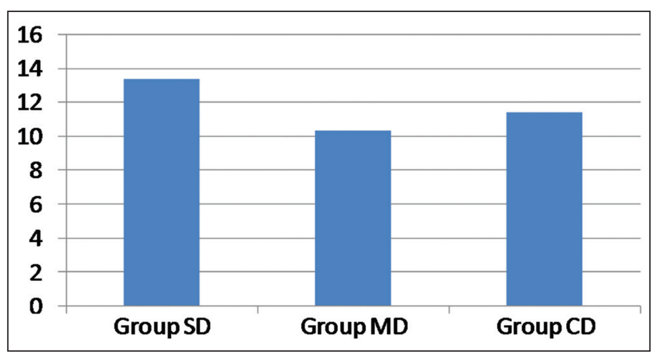


Figure 4: In dry condition

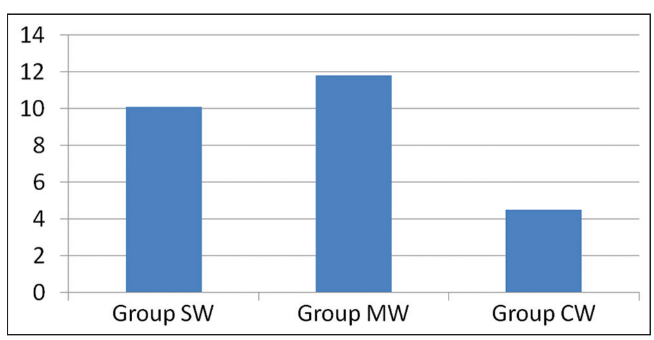
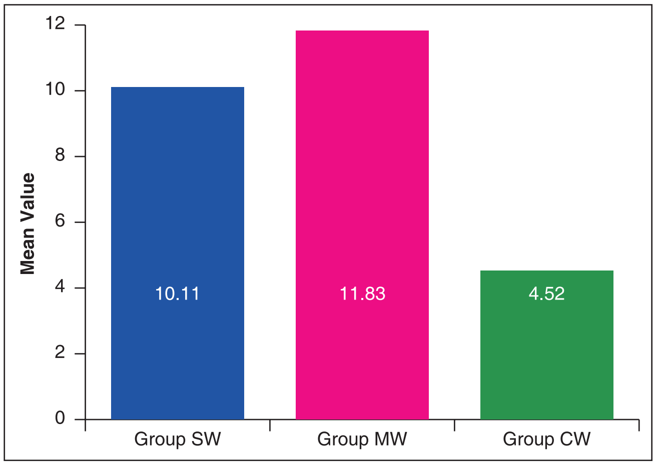


Figure 5: In wet conditions



Graph 2: Comparison of mean bond strength among three groups — dry condition

Table 2: Multiple comparison-group comparison between dry and wet condition

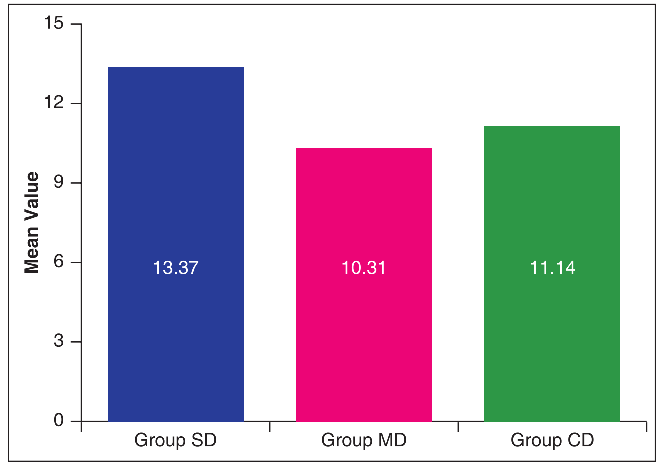
Group (I)	Group (J)	Mean difference (I-J)	*P* value
SW	SD	−3.2593	0.001 VHS
	MW	−1.7220	0.001 VHS
	MD	−0.2067	0.959 NS
	CW	5.6007	0.001 VHS
	CD	−1.0280	0.001 VHS
SD	MW	1.5373	0.001 VHS
	MD	3.0527	0.001 VHS
	CW	8.8600	0.001 VHS
	CD	2.2313	0.001 VHS
MW	MD	1.5153	0.001 VHS
	CW	7.3227	0.001 VHS
	CD	0.6940	0.063 NS
MD	CW	5.8073	0.001 VHS
	CD	−0.8213	0.015 S
CW	CD	−6.6287	0.001 VHS

VHS – Very highly significant; S – Significant; NS – Nonsignificant

These primers may be used in situations of minimal moisture contamination since they are purported to be hydrophilic. Thus, it would seem that self-etching primers are easier to handle and are effective in situations where moisture contamination is inevitable.[9]

In this study, a hydrophilic primer Transbond MIP by Unitek was also used. The hydrophilic component HEMA is dissolved in acetone and is recommended for use with composite resins.[6]

Maintaining a sound unblemished enamel surface after debonding orthodontic brackets is a primary concern of the clinician. As a result, bond failure at the bracket-adhesive interface or within the adhesive is more desirable than failure at the adhesive/enamel interface because enamel fracture and crazing have been reported at the time of bracket debonding with excessive bond strength. Hence the mode of bond failure was also compared for the three primers.



Graph 1: Comparison of mean bond strength among three groups — wet condition

In this study, an *in vitro* bond strength characterization was chosen due to the relative simplicity, increased reliability of simulating debonding techniques and mode of load application by shear force. Shear bond strength was tested because most masticatory forces are of a shearing nature.

Extracted premolar teeth were selected for this study, since they were easily available. Bondable 0.022 slot stainless steel PEA, Roth prescription (American Orthodontics) premolar brackets were selected for this study.

All primers under dry conditions exhibited bond strength more than the minimum required bond strength.[11] In wet condition only self-etching primer and MIP showed adequate bond strength.

Thermocycling simulates the temperature dynamics in the oral environment; with direct bonding it reduces the bond strength of orthodontic adhesives.[12] Orthodontic adhesives are routinely exposed to temperature variations in oral cavity. Air temperature, humidity, and air velocity when breathing can also alter resting mouth temperature.[13] Although these variations are erratic and hard to anticipate when testing, it is important to determine whether they introduce stresses in the adhesive that might influence its bond strength. Gasgoos in 2009 reported that the shear bond strength of 3M/Unitek and Clearfil before thermocycling and after 500 thermocycle was not significantly changed. This result is supported by Hasegawa *et al.*[14] who reported that subjecting specimens to 500 cycles might not affect bond strength, depending on the adhesive system used. Other study shows in its results a reduction in shear bond strength of self-etch primer, but after 10,000 thermocycles.[15]

Moisture contamination, which inhibits the micromechanical bond between enamel and cement, is one of the leading causes of bond failure.[16,17] The high premolar bond failure rate in a 5-year retrospective clinical study was attributed to the presence of prismless enamel and to the difficulty of moisture control in this area.[18] The significantly higher failure rate of premolars in a randomized, prospective, split mouth clinical study was partially attributed to moisture contamination.[19] After only 1 s contamination, oral fluids obscure the etched enamel surface and cannot be adequately removed for bonding purposes.[20] Obviously, moisture is an inherent condition when bonding in the oral cavity, and a dry field is not always possible. Therefore, a bonding system that provides adequate bond strengths, while tolerating moisture would be ideal. Some studies have shown that ethanol and acetone-based restorative primers bond well to the wet dentine and enamel surfaces. Research also supports the claim that a hydrophilic orthodontic primer (i.e., Transbond™ MIP) with an ethanol base has high shear — peel bond strengths, even in the presence of moisture. However, there are also reports suggesting that the use of MIP primer decreases bond strengths in dry fields or when applied on a moistened enamel surface compared with dry fields. As the effect of moisture on the bond strength of a hydrophilic orthodontic primer appears to be controversial, the purpose of this study was to determine whether, a hydrophilic primer, Transbond™ MIP (MIP), could produce equal or greater shear/peel bond strengths than a control primer, Transbond™ XT (XT), in moist or dry conditions and if there was a significant difference in the area of bond failure.[21]

A subsequent study conducted by Prasad reported that among the conventional bonding system groups, a dry enamel surface condition showed high bond strength (16.38 MPa), when compared with wet conditions. Moisture and saliva contamination had little influence on the shear bond strength, with mean shear bond strengths of 14.15 and 13.66, respectively. The shear bond strength between moisture and saliva had no significant result.[22]

Analysis of the results of the study showed that self-etching primer displayed superior bond strength when compared with Tranbond XT primer and MIP under dry condition. This finding is analogous to a study in which it was found that self-etching primer in dentin exhibited higher bond strength compared with conventional primer in spite of their limited resin infiltrated dentin layer thickness.[23]

However, under wet condition, the present study showed MIP superior to the self-etching primer. The findings were in direct contrast to those of who established that the bond strength values of self-etching primer were clinically adequate, but inferior to conventional primers. It was also found that the micro-tensile strengths of self-etching primers on underground enamel were less when compared with conventional primers.[24]

Moisture insensitive primer showed greater bond strength in wet conditions. This finding is similar to the study, in which it was found that MIP displayed comparable bond strengths under both dry and wet conditions.[6]

When compared with conventional Transbond XT primer, MIP was comparable to Tranbond XT primer in dry conditions and considerably superior under wet conditions. Transbond XT primer showed a remarkable reduction in bond strength in wet conditions well below the minimum required bond strengths for Orthodontic purpose.

These finding were in direct contrast to the results of the study which established that MIP was inferior to conventional primer under dry conditions but the mean bond strength was promising and his results was based on Weibull analysis.[7] The nature of debonding is evaluated using the ARI score, which defines the site of bond failure.

In this study, the debonding character of each specimen was determined with modified ARI under × 10 magnification. Conventional Transbond XT primer in dry field had an ARI score of 1 for 40% of the specimens, showing debonding at the bracket-adhesive interface with excessive resin left on the enamel surface.

About 50% of MIP samples under dry conditions had an ARI score of three showing debonding within the adhesive itself. Self-etching primer also showed similar results under dry conditions.

Thus, all three samples under dry conditions showed debonding at the bracket/adhesive interface. This has the advantage of minimal enamel damage, but increases the necessities for clean-up. However, Transbond XT primer showed more adhesive remaining on the tooth surface when compared to MIP and self-etching primer in dry condition.

However, under wet conditions 85% of Transbond XT primer samples showed an ARI score of 5. Taking into consideration, the low bond strengths of Transbond XT under wet conditions, this reflects an inability of the resin to flow into the saliva contaminated enamel surface and does not reflect debonding at the enamel-adhesive interface.

Moisture insensitive primer showed debonding within the adhesive leaving behind moderate amounts of adhesive, however self-etching primer showed excessive adhesive left behind. This is similar to the study where self-etching primer left behind fewer adhesives than conventional primer in dry conditions. However in wet conditions, self-etching primer leaves behind more adhesive.[25]

The depth of infiltration of self-etching primer is reported to be less when compared to conventional primers.[21] However, their superior bond strength and their tendency to leave behind more adhesive under wet conditions could be attributed to the continuous layer that is formed between the composite resin and the tooth surface by simultaneous demineralization with acidic monomers followed by bonding agent penetration into etched enamel.

Thus, MIP would be the obvious choice in cases of moisture contamination. Self-etching primer would also be a good choice. However in dry condition conventional Transbond XT primer performed equally well in terms of bond strength. Furthermore, self-etching primers would not be useful for rebonding single bond failures since the unit has to be used within 1 h of activation. This would involve wastage. Hence, use of the more expensive self-etching primer in dry condition is not imperative.

CONCLUSION

A comparative evaluation of the shear bond strength was undertaken with three different primers namely self-etching, moisture insensitive and conventional light cured primers under both dry and wet conditions and the following conclusions were drawn:

Under dry condition the shear bond strength of conventional primer was comparable to MIP and self-etching primer. However the cost effectiveness of conventional primer makes it the material of choice.

Under wet conditions MIP showed the highest bond strength and hence can be considered as a material of choice in wet conditions.

Self-etching primer also can be considered in wet conditions; however its relative high cost makes its use a matter of individual preference.

Although the present study offered encouraging clinical possibilities, it must be accepted with guarded optimism. Furthermore, clinical trial of all these materials should be under taken in order to obtain a clearer and more comprehensive picture.

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