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Comparative evaluation of shear bond strength of conventional primer and moisture insensitive primer in dry and wet conditions for bonding orthodontic ceramic brackets: An *in vitro* study

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Abstract
Objective: To evaluate and compare the shear bond strength of conventional primer and moisture insensitive primer (MIP) in dry and wet conditions for bonding orthodontic ceramic brackets and to assess the Adhesive Remnant Index (ARI) following debonding.
Method: Forty extracted human premolars were randomly divided into four groups of ten specimens each. Group I consisted of ceramic brackets bonded using Transbond XT primer under dry conditions. Group II consisted of ceramic brackets bonded using Transbond XT primer under wet conditions. Group III consisted of ceramic brackets bonded using Transbond Moisture Insensitive Primer under dry conditions. Group IV consisted of ceramic brackets bonded using Transbond Moisture Insensitive Primer under wet conditions. Shear bond strength was evaluated using a universal testing machine and ARI scores were recorded under stereomicroscopic examination.
Result: The highest mean shear bond strength was observed in Group III (35.45±3.36 MPa), followed by Group I (31.49±5.64 MPa), Group IV (19.70±0.71 MPa), and Group II (10.17±2.66 MPa). One-way ANOVA showed a highly significant difference among the groups (F=104.166, p<0.001). Intergroup comparison demonstrated statistically significant differences between all groups except Group I and Group III. ARI scores were predominantly 2 and 3 in dry groups and lower in the conventional wet group.
Conclusion: Moisture contamination significantly reduced the shear bond strength of the conventional primer system. Moisture Insensitive Primer demonstrated superior performance under wet conditions and maintained clinically acceptable bond strength. Under dry conditions both primer systems showed comparable bond strength values.

Keywords: Shear bond strength, moisture insensitive primer, conventional primer, ceramic brackets, adhesive remnant index

Introduction

The development of the acid etch technique by Buonocore in 1955 led to the direct bonding of orthodontic brackets with composite resin. This development resulted in improvements in orthodontic treatment such as greater comfort for the patient, elimination of pretreatment separation, decreased gingival irritation, easier oral hygiene, improved aesthetics, and reduced chairside time [1]. This technique was suggested for orthodontic use by Newman [2] and is now widely accepted. The merits of direct bonding include benefits for both the patient and the practitioner. For the patient, there is less risk of enamel decalcification, easier plaque control, decreased irritation of the gingival tissue, and improved aesthetics. For the practitioner, direct bonding makes it easier to detect and treat dental caries, eliminates pretreatment separation of the teeth, and decreases chair-side time. Etching with phosphoric acid formulations has a number of effects on the enamel surface. The resin flows into the porosities and results in the formation of retentive tags, which bond the resin mechanically to the etched enamel surface [2]. Etching, rinsing, and thorough drying of enamel significantly increases its surface energy, enabling effective wetting by the adhesive resin. However, this process is highly technique sensitive. Any deviation from optimal bonding conditions, particularly the presence of moisture contamination, can compromise resin infiltration and reduce bond strength. Among all factors affecting bonding efficacy, moisture contamination is considered the most common cause of bond failure in orthodontic practice [2, 3, 4].

Traditional composite resin bonding materials and methods mandate completely dry and isolated fields to obtain clinically acceptable bond strength. However, a variety of clinical conditions do not permit ideal isolation for commonly used orthodontic bonding adhesives and protocols. To address this reality, some manufacturers have introduced hydrophilic bonding materials and suggested that it may be possible to obtain successful orthodontic bonding to a moisture contaminated enamel surface [5]. Transbond Moisture Insensitive Primer (MIP; 3M Unitek, Monrovia, CA, USA) is one such system designed to improve bonding reliability under moist conditions Transbond MIP (3M Unitek Dental Products, Monrovia, Calif), is recommended by the manufacturer for use on dry or wet etched enamel in conjunction with either chemical- or visible-light-activated resin-based adhesives [2].

Numerous studies have evaluated the shear bond strength of stainless-steel orthodontic brackets bonded with different primer systems. However, there is a relative lack of studies comparing the shear bond strength of orthodontic ceramic brackets bonded with conventional primers and moisture-insensitive primers under both dry and wet conditions.

Therefore, the purpose of the present study is to evaluate and compare the shear bond strength of conventional primer and moisture-insensitive primer (3M Transbond MIP) under dry and wet (contaminated) conditions for bonding orthodontic ceramic brackets

Materials and Method

This *in vitro* experimental comparative study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics Pacific Dental College and Hospital, Udaipur.

A total of forty extracted human premolars were collected from the Department of Oral and Maxillofacial Surgery of Pacific Dental College and Hospital, Udaipur. Teeth with intact enamel surfaces, normal morphology, and without developmental defects, restorations, or cracks were included in the study.

The teeth were cleaned and stored in 0.1% Thymol (Mark Solutions, India) until use. All specimens were embedded in cold cure acrylic resin blocks and randomly divided into four groups of ten samples each.

Group I

Conventional Primer – Dry

Ceramic brackets were bonded using Transbond XT primer and Transbond XT adhesive under dry conditions.

Group II

Conventional Primer – Wet

Ceramic brackets were bonded using Transbond XT primer and Transbond XT adhesive under wet conditions. Artificial saliva contamination was produced by applying two coats of artificial saliva to the etched enamel surface and blot drying excess saliva.

Group III

Moisture Insensitive Primer – Dry

Ceramic brackets were bonded using Transbond Moisture Insensitive Primer and Transbond XT adhesive under dry conditions.

Group IV

Moisture Insensitive Primer – Wet

Ceramic brackets were bonded using Transbond Moisture Insensitive Primer and Transbond XT adhesive under wet conditions and with the artificial saliva contamination.

After bonding, all specimens were subjected to shear bond testing using a universal testing machine (Instron). Force was applied at the bracket-tooth interface at a crosshead speed of 1 mm/minute in an occluso-gingival direction until debonding occurred.

Following debonding, all samples were examined under a stereomicroscope at 10× magnification and ARI scores were recorded.

Statistical Analysis

Statistical analysis was performed using SPSS software. Descriptive statistics including mean and standard deviation were calculated. Intergroup comparisons were performed using One-Way Analysis of Variance (ANOVA) followed by Tukey's post hoc test. ARI scores were analysed using the Chi-square test. A p-value less than 0.05 was considered statistically significant.

Results

Table 1: Evaluation of mean Shear Bond Strength of Group I, II, III and IV

	Mean	SD	SE
Group I	31.49	5.64	1.78
Group II	10.17	2.66	0.84
Group III	35.45	3.36	1.06
Group IV	19.70	0.71	0.22

Table 2: Comparison of Shear Bond Strength (MPa) of Group I, II, III and IV

	Mean	SD	One-way Anova F test	P value
Group I	31.49	5.64	F = 104.166	p < 0.001**
Group II	10.17	2.66		
Group III	35.45	3.36		
Group IV	19.70	0.71		

Table 3: Intergroup comparison of shear bond strength of Group I, II, III and IV

Group	Comparison Group	Mean Difference	P value, Significance
Group I	Group II	21.33	p< 0.001**
	Group III	3.95	P=0.081 (NS)
	Group IV	11.79	p< 0.001**
Group II	Group III	25.29	p< 0.001**
	Group IV	9.54	p< 0.001**
Group III	Group IV	15.73	p< 0.001**

Discussion

The present study evaluated and compared the shear bond strength of ceramic brackets bonded using conventional primer and moisture insensitive primer under dry and wet conditions.

The results demonstrated that moisture contamination significantly reduced the shear bond strength of the conventional primer system. The lowest SBS value was observed in Group II (10.17±2.66 MPa), indicating the adverse effect of moisture contamination on conventional hydro phobic primers.

The highest SBS value was observed in Group III (35.45±3.36 MPa). Although Group III showed higher SBS than Group I (31.49±5.64 MPa), the difference was statistically non-significant, indicating that both primers perform comparably under dry conditions.

The findings of the present study are in accordance with Roy *et al.* (2025) [6], who reported that moisture significantly affected SBS and ARI values and that moisture insensitive primer was more resistant to moisture contamination than conventional primer.

Table 4: Frequency and percentage distribution of the ARI scores of Group I, II, III and IV

	Score 0 n (%)	Score 1 n (%)	Score 2 n (%)	Score 3 n (%)
Group I	0 (0%)	0 (0%)	7 (70%)	3 (30%)
Group II	1 (10%)	8 (80%)	1 (10%)	0 (0%)
Group III	0 (0%)	0 (0%)	7 (70%)	3 (30%)
Group IV	0 (0%)	4 (40%)	6 (60%)	0 (0%)

*p<0.05- significant difference, Chi-square = 28.381

Rajan and Mailankody (2022) [7] reported SBS values ranging from 16.22–17.4 MPa for Transbond MIP under wet conditions, which were comparable to the findings of the present study. They concluded that the clinical use of MIP in wet environments is recommended.

Abbassy *et al*. (2021) [8] observed that although SBS values of MIP decreased under moist conditions, they remained within clinically acceptable limits. Similar findings were observed in the present study, where SBS decreased from 35.45 MPa under dry conditions to 19.70 MPa under wet conditions but remained clinically acceptable.

Kumar *et al*. (2018) [9] reported that MIP demonstrated superior bond strength compared with Transbond XT under saliva-contaminated conditions and recommended its use when moisture control is difficult. These findings support the observations of the present study.

John *et al*. (2015) [10] reported that MIP demonstrated the highest bond strength under wet conditions compared with self-etching primer and conventional primer systems. Similar findings were observed in the present investigation.

The higher SBS values observed in the present study compared with many previous studies may be attributed to the use of ceramic brackets. Reddy *et al* [11]. reported that ceramic brackets demonstrate higher bond strength than metallic brackets, which may explain the higher values obtained in this study.

ARI evaluation demonstrated higher scores of 2 and 3 in dry groups, indicating bond failure predominantly at the bracket-adhesive interface. In contrast, lower ARI scores were observed in the conventional wet group, indicating failure at the enamel-adhesive interface due to inadequate resin penetration which is caused by the moisture contamination.

Although MIP demonstrated a reduction in SBS under wet conditions compared with dry conditions, its bond strength remained well above the clinically acceptable range. Therefore, MIP may be considered a reliable alternative in clinical situations where ideal moisture control cannot be achieved.

The limitation of the present study is its *in vitro* design. Clinical conditions such as salivary enzymes, temperature fluctuations, masticatory forces, and oral hygiene factors could not be simulated completely. Therefore, further *in vivo* studies are recommended.

Conclusion

- Moisture insensitive primer under dry conditions demonstrated the highest mean shear bond strength.
- Conventional primer and moisture insensitive primer showed comparable bond strength under dry conditions.
- Moisture contamination significantly reduced the bond strength of the conventional primer system.
- Moisture insensitive primer showed significantly higher bond strength than conventional primer under wet conditions.
- Dry condition groups demonstrated higher ARI scores, which indicates that failure is predominantly at the bracket-adhesive interface.
- Moisture insensitive primer maintained clinically acceptable bond strength under wet conditions and may be considered a reliable bonding system when moisture control is compromised.

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