ORIGINAL RESEARCH

Assessment of Microleakage under Stainless Steel Orthodontic Brackets Bonded with Various Adhesive Systems: An *In Vitro* Study

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Abstract

Aim and objective: The aim of this study was to evaluate the extent of microleakage beneath stainless steel orthodontic brackets bonded with different adhesive systems.

Materials and methods: Freshly extracted 60 human premolar teeth from mandibular arch were included in this study. After sterilizing all teeth, they were stored in thymol solution of 1% for further preparation. Acrylic blocks were used to mount the teeth in a way their roots were totally implanted up to the cement enamel junction in acrylic with crown being visible. A 0.022 slot, stainless steel preadjusted edgewise premolar brackets were taken. Sixty premolars were categorized randomly into three groups (20 premolars in each group) as follows: group I: flowable composite, group II: Fuji Ortho LC, group III: Transbond XT. Later, all the samples were subjected to thermocycling and tested immediately and 24 hours after water storage. The samples were submerged for 24 hours in methylene blue solution (2%) at room temperature. A ×20 magnification stereomicroscope was used to examine all samples.

Results: The lowest microleakage (1.34 ± 0.20) was shown by Transbond XT restored teeth, followed by flowable composite group (1.79 ± 0.32) and Fuji Ortho LC group (2.98 ± 0.13). An analysis of variance showed statistically significant differences among various adhesive systems. A statistically significant difference ($p < 0.05$) among groups I and II, and groups II and III adhesive materials was seen.

Conclusion: This study demonstrated microleakage in all the examined adhesive groups but the lowest microleakage was found with Transbond XT group followed next by Filtek Z350 XT group and Fuji Ortho LC group.

Clinical significance: Due to microleakage, the bacteria and fluids present intraorally penetrate through the gaps along the enamel-adhesive boundary. This penetration results in significant esthetic and clinical complications. Such problems related to microleakage can be addressed with the use of an appropriate adhesive agent.

Keywords: Adhesive, Brackets, Dye penetration, Microleakage.

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Introduction

The success of an orthodontic treatment relies on an effective bond between the tooth surface and orthodontic bracket so as to tolerate the thermal and mechanical effects of the oral cavity. In dentistry, one of the most investigated areas is bonding systems. Bonding systems are also being continuously invented in orthodontics with the newest entrants being self-etching primer and moisture insensitive primer.[1]

Although the bond between enamel surface and bracket base is temporary, it must be adequately strong to resist the shear forces and stresses. Nonretention of bracket base, failure of the bonding method, and presence of masticatory forces lead to dislodgment of orthodontic fixtures, thus resulting in a common clinical error in orthodontic practice due to disturbance, postponement of treatment, and increase in associated costs.[2]

The existence of acquired salivary pellicles during bonding may impact the bond strength between enamel and orthodontic adhesives. It has been shown that acquired salivary pellicle may functionally help in maintaining homeostasis of enamel's mineral component. It has been demonstrated by substantial evidence that salivary pellicle develops by selective adsorption of peptides, proteins, and other substances present intraorally. Every solid surface present intraorally gets coated by a proteinaceous film called as the acquired pellicle.[3]

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In restorative dentistry, microleakage develops due to the diffusion of oral fluids and bacteria along the borders of tooth and restoration. Microleakage has been considered as a significant problem in fixed orthodontic appliance treatment as it leads to reduced marginal integrity ensuing as white-spot lesions beneath and around the bracket surface area resulting in bond failure.[4] The different factors contributing to microleakage are insufficient adhesion, dissimilar thermal expansion of the adhesive and enamel, and polymerization shrinkage of the resin.[5] There has been no study that has related the microleakage of all adhesive systems at the same time. So, the present study was conducted to evaluate the microleakage beneath stainless steel orthodontic brackets bonded with flowable composite, Fuji Ortho LC, and Transbond XT adhesive systems.

Materials and Methods

Preparation of Samples

The present *in vitro* study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Purvanchal institute of dental sciences, India. Totally, 60 recently extracted human premolar teeth from mandibular arch were used for this study. Distilled water solution was used to store teeth. Just before bonding, scaler and pumice were used to clean teeth by removing plaque and soft-tissue fragments. Structurally sound, unbroken mandibular first premolars with no caries, discoloration, and hypoplasia were extracted for orthodontic purposes and were included in this study. Teeth that had decay, attrition, developmental anomalies, visible cracks, and restorations were excluded from this study. Sterilization of all teeth was performed and was kept in 1% thymol solution until further preparation. The teeth were mounted on acrylic blocks such that the roots were completely embedded in the acrylic up to the cement enamel junction leaving the crown portion exposed.

Placement of Orthodontic Bracket

Stainless steel bondable 0.022 slot preadjusted edgewise appliances (Roth prescription) premolar brackets (American Orthodontics, USA) were used. The mean bracket base area was estimated to be 8.686 mm^2.

Bonding Procedure

Sixty premolars were randomly separated into three groups (20 premolars in each group) as mentioned below.

Group I: Flowable Composite

Based on the manufacturer's instructions, a thin coat of primer (Adper adhesive systems; 3M ESPE, Seefeld, Germany) was applied over the etched surface and cured with light for 10 seconds. Composite (Filtek Z350 XT) was used to position the bracket and cured for 20 seconds.

Group II: Fuji Ortho LC

The complete bracket base was covered by the placement of Fuji Ortho LC (GC International Corp., Tokyo, Japan), with no voids or bubbles, on the bracket mesh. This was followed by placement of the bracket onto the tooth using adequate force to remove excess adhesive surrounding the bracket so that a consistent thickness of adhesive remains and brackets are adjusted to the final position and pressed firmly. The extra adhesive present around the tooth surface was removed. Each part of the tooth surface was light cured for a period of 10 seconds (totally 40 seconds).

Group III: Transbond XT

A phosphoric acid gel of 37% was used to etch the teeth for 15 seconds, following which the teeth were rinsed and dried using an oil-free air spray for 20 seconds. The etched enamel surfaces were coated with Transbond XT primer, and Transbond XT adhesive (3M Unitek, California, USA) was used to bond the brackets.

After completion of bonding method, all samples were stored for 24 hours in distilled water, then exposed between 5 and 55°C to 500 thermocycles in baths of distilled water with a residing time of 30 seconds and it took 5–10 seconds for a change among baths. Subsequently, all the samples were tested after thermocycling and after 24 hours of water storage.

Evaluation of Microleakage

Subsequent to individual storage period, the teeth were dehydrated and two coatings of nail polish were applied all over the exposed surface except 1 mm around the bracket base edges. Later, the samples were submerged in methylene blue (2%) at room temperature for 1 day. After 1 day, the samples were meticulously washed to remove remnant dye and a sharp instrument was used to remove the nail varnish. A low-speed diamond saw (Isomet, Buehler, Illinois, USA) was used to make four parallel sections running longitudinally in the buccolingual direction. A stereomicroscope of ×20 magnification was used to examine all samples. All the sections were scored from both gingival and incisal margins to the brackets between both the adhesive-enamel interfaces and bracket-adhesive. Two operators evaluated all the samples at two different times so as to estimate the error related to measurement. The intraexaminer and interexaminer Kappa scores for evaluation of microleakage were more than 0.80. Scoring was done using below mentioned criteria.

- Score 0—No dye penetration between the adhesive-enamel interface or bracket-adhesive
- Score 1—Dye penetration limited to 1 mm of the adhesive-enamel interface or bracket-adhesive
- Score 2—Dye penetration into the inner half (2 mm) of the adhesive-enamel interface or bracket-adhesive
- Score 3—Dye penetration into 3 mm of the adhesive-enamel interface or bracket-adhesive

Statistical Analysis

This study used SPSS version 20. Statistical analysis was done using analysis of variance (ANOVA) test and by Tukey's post hoc test to determine the significance of the between-group differences. A p value of <0.05 was considered as statistically significant.

Results

The comparative mean microleakage of different adhesive systems is as shown in Table 1. The lowest microleakage (1.34 ± 0.20) was shown by Transbond XT restored teeth, followed by flowable composite group (1.79 ± 0.32) and Fuji Ortho LC group (2.98 ± 0.13). An ANOVA showed statistically significant differences among various adhesive systems.

The microleakage scores of various adhesive systems are as shown in Table 2. Score 0 [3(15%)] and score 1 [10(50%)] were more in Transbond XT group, and score 2 [10(50%)] and score 3 [5(25%)] were more in Fuji Ortho LC group.

Table 3 shows multiple comparisons between the adhesive systems. A statistically significant difference ($p < 0.05$) among

Table 1: Comparison of mean microleakage of various adhesive systems

Adhesive systems groups	*Mean ± SD*	*F value*	*P value*
Group I: Flowable composite	1.79 ± 0.32		
Group II: Fuji Ortho LC	2.98 ± 0.13	24.146	0.001
Group III: Transbond XT	1.34 ± 0.20		

Table 2: Microleakage scores of different adhesive systems

	Microleakage scores			
Groups	*Score 0*	*Score 1*	*Score 2*	*Score 3*
Group I: Flowable composite	2(10%)	9(45%)	7(35%)	2(10%)
Group II: Fuji Ortho LC	1(5%)	4(20%)	10(50%)	5(25%)
Group III: Transbond XT	3(15%)	10(50%)	6(30%)	1(5%)

Table 3: Comparisons of mean difference between the groups using Tukey HSD

Group	*Compared with*	*Mean difference (I–J)*	*Sig.*
Group I	Group II	−1.19	0.001*
	Group III	0.45	0.06
Group II	Group I	1.19	0.001*
	Group III	1.64	0.001*
Group III	Group I	−0.45	0.06
	Group II	−1.64	0.001*

*Significant, $p < 0.05$.

groups I and II, and groups II and III adhesive materials was seen. But, no significant difference ($p > 0.05$) was seen between groups I and III.

The inference of the present study indicates that the Transbond XT adhesive systems showed the lowest microleakage compared to Filtek Z350 XT and Fuji Ortho LC adhesive systems.

Discussion

The white-spot lesion which may possibly be irreversible and in aesthetic is considered as a serious adverse effect of fixed treatment applications and may develop within a month's time of treatment initiation. Thus, frequent examination of the area under and around the bracket is important, and the evaluation of microleakage can indicate the ability of adhesive materials to seal.[6]

In the present study, the microleakage of samples that were bonded was established by dye-penetration method, which is the most frequently used technique to evaluate microleakage of dental materials. This method is economical and can be performed easily and rapidly, but it is associated with interexaminer variability in reading the specimens.[7] In this study, two operators assessed all the samples at two different times so as to estimate the error related to measurement. The intraexaminer and interexaminer Kappa scores for evaluation of microleakage were more than 0.80.

In our study, reduced microleakage was demonstrated by Transbond XT adhesive group than flowable composite group (Filtek Z350 XT) and Fuji Ortho LC group. These results are different from those obtained by Hedayati et al.[8] who detailed that brackets bonded with Filtek Z350 showed significantly increased microleakage when compared to conventional composite material (Transbond XT).

The Transbond XT showed minimum microleakage value and Fuji Ortho LC group showed the maximum microleakage value between the chosen adhesive materials. However, these results were dissimilar from those reported by Yagci et al.[9] and Aliks et al.[4] who demonstrated that the bonding procedure or material did not impact the extent of microleakage beneath the brackets. Hamamci et al.[10] states that numerous aspects that may impact extent of microleakage are enamel conditioning, composition and category of adhesive, base design and bracket materials, and thermal expansion coefficients. Additionally, the increased microleakage seen with Fuji Ortho LC and the probability of enamel demineralization may be answered by remineralizing action of this adhesive in the demineralized enamel as shown by Ramoglu et al.[11]

Arikan et al.[12] and Uysal et al.[13] conducted *in vitro* studies to assess the microleakage beneath brackets in gingival and occlusal directions along the adhesive-bracket and enamel-adhesive interfaces. Our study used a comparable working process. The resultant microleakage scores from the gingival and occlusal margins of the brackets showed substantial differences, with maximum microleakage along the gingival margin. This result could be correlated to the surface anatomy of the teeth. Similar results were reported by Uysal et al.[14] and Arhun et al.[6]

The variation in oral cavity temperature impacts the bond between the tooth and the adhesive material. The dissimilar expansion coefficient within the "adhesive-bracket-enamel" complex causes diverse dimensional changes due to frequent contraction and expansion, thus resulting in oral liquids or water being trapped in and pushed out along the bracket edges, which may, in turn, lead to tooth cracks, fractures, and subsequent microleakage.[15] This has been one of the reasons for the use of broad thermal cycling processes in these studies. Furthermore, storage of water can reduce the bonding efficiency by breaking down the interface constituents due to hydrolysis. The water can penetrate the polymer matrix as well and weaken its mechanical characteristics.[16] The intraoral temperature variation can be simulated by thermal cycles, thus producing repeated thermal stresses along the adhesive-tooth border. Multiple trials, such as those conducted by Bedran-de-Castro et al.[17] and Ulker et al.,[18] have demonstrated that an upsurge in the quantity of thermal cycles does not relate to an increase in extent of microleakage of restorations.

The limitation of this *in vitro* study is that it was not possible to simulate the exact oral environment because of various conditions and variables present intraorally such as the saliva and its widely varying pH, enzyme and mineral composition, and changes in temperature. Thus, *in vivo* studies that could assess all these factors have to be conducted in future.

Conclusion

This study noticed microleakage in all the examined adhesive groups but the lowest microleakage was found with Transbond XT group followed next by Filtek Z350 XT group and Fuji Ortho LC group.

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