

Microleakage under Metallic and Ceramic Brackets Bonded with Orthodontic Self-Etching Primer Systems

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ABSTRACT

Objective: To compare the in vitro microleakage of orthodontic brackets (metal and ceramic) between enamel-adhesive and adhesive-bracket interfaces at the occlusal and gingival sides produced by self-etching primer system with that of conventional acid etching and bonding.

Materials and Method: Sixty freshly extracted human mandibular premolar teeth were used in this study. The teeth were separated into four groups of 15 teeth each and received the following treatments: Group 1, 37% phosphoric acid gel + Transbond XT liquid primer + stainless steel bracket; Group 2, Transbond Plus Self-Etching Primer (TSEP) + stainless steel bracket; Group 3, 37% phosphoric acid gel + Transbond XT liquid primer + ceramic bracket; Group 4, TSEP + ceramic bracket. After curing, specimens were further sealed with nail varnish, stained with 0.5% basic fuchsin for 24 hours, sectioned and examined under a stereomicroscope, and scored for microleakage for the enamel-adhesive and bracket-adhesive interfaces from both occlusal and gingival margins. Statistical analyses were performed using Kruskal-Wallis and Mann-Whitney *U* tests.

Results: The gingival sides in all groups exhibited higher microleakage scores compared with those observed in occlusal sides for both adhesive interfaces. Enamel-adhesive interfaces exhibited more microleakage than did the adhesive-bracket interfaces. Brackets bonded with self-etching primer system showed significantly higher microleakage at the enamel-adhesive interface of the gingival side.

Conclusions: TSEP causes more microleakage between enamel-adhesive interfaces, which may lead to lower bond strength and/or white-spot lesions.

KEY WORDS: Microleakage; Self-etching; Metallic; Ceramic bracket

INTRODUCTION

In routine orthodontic practice it is essential to obtain a reliable adhesive bond between an orthodontic attachment and tooth enamel. To simplify the orthodontic bonding procedure and reduce chair time, self-etch-

ing primers are manufactured to combine two or more bonding steps.¹

In late 2000, a new self-etching primer, Transbond-Plus Self-Etching Primer (TSEP: 3M-Unitek, Monrovia, Calif) was developed especially for orthodontic bonding. It includes methacrylated phosphoric acid esters, which will both etch and prime the enamel surface before bonding. TSEP has been experimentally tested in several in vitro tests¹⁻⁵ and revealed promising adhesive bonding results.^{3,4}

Although tooth-conserving and time-saving adhesive methods of retaining orthodontic attachments are replacing traditional methods and procedures, a significant caries risk under and in the vicinity of the multibonded appliances is of concern.^{6,7} According to Arhun et al,⁸ investigators in the literature^{9,10} were interested in decalcifications and white spots around the brackets, not under the brackets, and they pointed out that although the area around the brackets is critical, the area under the brackets also needs attention.

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The polymerization shrinkage of the adhesive material may cause gaps between the adhesive material and enamel surface and lead to microleakage, thus facilitating the formation of white-spot lesions under the bracket surface area.¹¹ Gap formation contributes to microleakage, permitting the passage of bacteria and oral fluids from the oral cavity.¹² It is well documented that microleakage increases the likelihood of recurrent caries and postoperative sensitivity.¹¹ From the orthodontic perspective, it is possible to interpret this fact as supportive of the formation of white spot lesions between the bracket and enamel interface. In the orthodontic literature, James et al¹¹ noted the increased risk of decalcification caused by microleakage around orthodontic brackets. Then Arhun et al⁸ assessed microleakage of a tooth-adhesive-bracket complex when metal or ceramic brackets were bonded with a conventional and an antibacterial adhesive. They found that metal brackets caused more leakage between the adhesive-bracket interface, which may lead to lower clinical shear bond strength and white-spot lesions. Arian et al¹³ investigated different light-curing units and bracket types for microleakage observed beneath brackets and concluded that ceramic brackets cured with light-emitting diode units were the best combination, demonstrating the lowest microleakage scores.

So far, to our knowledge, no studies have been reported investigating the effect of an orthodontic self-etching primer system on microleakage under brackets. The aim of this study was to compare the in vitro microleakage of orthodontic brackets (metal and ceramic) between enamel-adhesive and adhesive-bracket interface at the occlusal and gingival sides produced by self-etching primer systems with that of a conventional acid-etching system. For the purposes of this study, the null hypothesis assumed that there were no statistically significant differences between the microleakage of an enamel-adhesive-bracket complex at the occlusal and gingival margins and enamel prepared by TSEP and by a conventional-etching method.

MATERIALS AND METHODS

Sample Preparation

Sixty freshly extracted human mandibular premolar teeth were used in this study. Teeth were stored in distilled water solution. Immediately before bonding, teeth were cleaned with scaler and pumice to remove soft-tissue remnants, callus, and plaque. Teeth were separated into four groups of 15 teeth each.

Specimens were prepared for bracket bonding according to one of the following procedures:

Group 1: Fifteen premolars were separated; a 37% phosphoric acid gel (3M-Dental Products, St Paul, Minn) was used to etch for 30 seconds. The teeth were then rinsed with water from a 3-in-1 syringe for 30 seconds and dried with an oil-free air source for 20 seconds. After surface preparation, the liquid primer Transbond XT (3M-Unitek) was applied to the etched surface and not cured. Standard edgewise premolar stainless steel brackets (3M) were bonded by standard protocol.

Group 2: Fifteen premolar teeth were separated; TSEP was gently rubbed onto the surface for approximately 3 seconds with the disposable applicator supplied with the system. A moisture-free air source was then used to deliver a gentle burst of air to the enamel. Standard edgewise premolar stainless steel brackets (3M-Unitek) were bonded to the teeth using the standard protocols, according to the manufacturer's instructions.

Group 3: This group was treated the same as Group 1, except that ceramic brackets (3M-Unitek) were bonded to the teeth.

Group 4: Enamels in this group was prepared the same as Group 2, except that ceramic brackets (3M-Unitek) were bonded by standard protocol.

All metallic and ceramic brackets were bonded to the teeth with Transbond XT light-cure adhesive paste, according to the manufacturer's instructions. Excess resin was removed with an explorer before it was polymerized. A quartz-tungsten halogen light unit (Hilux 350, Express Dental Products, Toronto, Canada) with a 10-mm diameter light tip was used for curing the specimens for 40 seconds.

Microleakage Evaluation

Before dye penetration, the teeth apices were sealed with sticky wax. After that, the teeth were rinsed in tap water and air dried. Nail varnish was then applied to the entire surface of the tooth except for approximately 1 mm away from the restorations. To minimize dehydration of the restorations, the teeth were replaced in water as soon as the nail polish dried. The teeth were immersed in 0.5% solution of basic fuchsin for 24 hours at room temperature. After being removed from the solution, the teeth were rinsed in tap water, and the superficial dye was removed with a brush and dried. Four parallel longitudinal sections were made through the occlusal and gingival surfaces with a low-speed diamond saw (Isomet, Buehler, Lake Bluff, Ill) in the bucco-lingual direction according to Arhun et al.⁸ Each section was scored from both occlusal and gingival margins to the brackets between both the enamel-adhesive and the adhesive-bracket interface. Microleakage was determined by direct measurement

Table 1. Descriptive statistics and comparison of the microleakage scores between occlusal and gingival sides for enamel-adhesive and adhesive-bracket interface^a

Interface	Groups ^b	N	Occlusal			Gingival			Statistical Evaluation
			Mean	SD	SEM	Mean	SD	SEM	
Enamel-adhesive interface	Group 1	15	0.000	0.000	0.000	0.083	0.154	0.040	NS
	Group 2	15	0.050	0.140	0.036	0.367	0.364	0.094	NS
	Group 3	15	0.017	0.065	0.017	0.050	0.140	0.036	**
	Group 4	15	0.050	0.140	0.036	0.433	0.291	0.075	**
Adhesive-bracket interface	Group 1	15	0.000	0.000	0.000	0.083	0.262	0.068	NS
	Group 2	15	0.000	0.000	0.000	0.317	0.320	0.083	*
	Group 3	15	0.000	0.000	0.000	0.083	0.122	0.032	***
	Group 4	15	0.000	0.000	0.000	0.000	0.000	0.000	NS

^a N indicates sample size; NS, not significant; SD, standard deviation; SEM standard error mean; **P* < .05; ***P* < .01; ****P* < .001.
^b Group 1: Acid + Transbond XT Primer + Metallic Bracket; Group 2: TSEP + Metallic Bracket; Group 3: Acid + Transbond XT Primer + Ceramic Bracket, Group 4: TSEP + Ceramic Bracket.

using an electronic digital caliper, and data were recorded to the nearest value as a range 0.5–5 mm.

Statistical Analysis

For each adhesive interface investigated (enamel adhesive and adhesive bracket), the microleakage score was obtained by calculating mean occlusal and gingival microleakage scores. For each specimen, the microleakage score was obtained by calculating the mean of occlusal and gingival microleakage scores measured from four sections. Statistical analyses were performed using Kruskal-Wallis and Mann-Whitney *U* tests (SPSS, version 13.0, Chicago, Ill). Intra- and interexaminer method error was evaluated by Kappa test. The level of statistical significance was set at *P* < .05.

RESULTS

Comparisons of the microleakage scores between occlusal and gingival sides for enamel-adhesive and adhesive-bracket interfaces are shown in Table 1. Microleakage was observed in all groups except Group 1 at the occlusal side between enamel-adhesive, and all groups at the occlusal side between adhesive-bracket interfaces. In all groups the gingival sides exhibited higher microleakage scores compared with those observed in the occlusal sides for both adhesive interfaces. For enamel-adhesive interface, ceramic brackets showed higher microleakage on the gingival than on the occlusal side (*P* < .01). When the self-etching primer was used for metallic brackets (*P* < .05) and conventional etching was used for ceramic brackets (*P* < .001), less microleakage was determined on the occlusal side. Therefore, the null hypothesis was rejected in part.

Statistical comparisons of the microleakage scores among four groups at the occlusal and gingival sides between enamel-adhesive and adhesive-bracket inter-

faces are shown in Table 2. According to statistical analysis, in both adhesive interfaces all groups displayed similar microleakage under the occlusal side of the brackets, and scores were not statistically different (*P* > .05). Statistically significant differences were found at the gingival sides between enamel-adhesive (*P* < .001) and adhesive-bracket (*P* < .01) interfaces among all investigated groups. Therefore, the null hypothesis was rejected. Brackets bonded with TSEP (Groups 2 and 4) revealed statistically higher microleakage between enamel-adhesive interfaces at the gingival side. When microleakage at the adhesive-enamel interface was considered, metal brackets bonded with TSEP (Group 2) showed the highest scores and ceramic brackets bonded with TSEP (Group 4) showed the lowest scores at the gingival side.

DISCUSSION

Enamel etching with phosphoric acid created an etch pattern characterized by a deep and uniform demineralization area. These demineralized areas were infiltrated by the resin of the priming solution, producing resin tags penetrating into demineralized surface.¹⁴ Compared with phosphoric acid, TSEP produced a uniform and more conservative etch pattern with regular adhesive penetration and a less aggressive enamel demineralization.¹⁴ When any problem exists during bonding process, it is possible for seeping and leaking of fluids and bacteria to occur between enamel-adhesive interfaces, and we can interpret these as the potential white-spot lesion on the enamel surface. A review of the literature indicated that no studies have compared the microleakage of metallic and ceramic brackets bonded with orthodontic composites to enamel that have been prepared with conventional acid etching and TSEP procedures.

In this study, the dye-penetration method was cho-

Table 2. Multiple comparisons of the microleakage scores between groups for occlusal and gingival sides in enamel-adhesive and adhesive-bracket interface

Interface	Side	Groups	N	Mean	SD	Significance (<i>P</i>)	Multiple Comparison		
							Group 2	Group 3	Group 4
Enamel-adhesive interface	Occlusal	Group 1	15	0.00	0.00	0.466			
		Group 2	15	0.05	0.14				
		Group 3	15	0.02	0.06				
		Group 4	15	0.05	0.14				
	Gingival	Group 1	15	0.08	0.15	0.000	*		
		Group 2	15	0.37	0.36				**
		Group 3	15	0.05	0.14				**
		Group 4	15	0.43	0.29		**	**	
Adhesive-bracket interface	Occlusal	Group 1	15	0.00	0.00	1.000			
		Group 2	15	0.00	0.00				
		Group 3	15	0.00	0.00				
		Group 4	15	0.00	0.00				
	Gingival	Group 1	15	0.08	0.26	0.001	*		
		Group 2	15	0.32	0.32				**
		Group 3	15	0.08	0.12				
		Group 4	15	0.00	0.00		**		

^a N indicates sample size; NS, not significant; SD, standard deviation; **P* < .05; ***P* < .01.

^b Group 1: Acid + Transbond XT Primer + Metallic Bracket; Group 2: TSEP + Metallic Bracket; Group 3: Acid + Transbond XT Primer + Ceramic Bracket, Group 4: TSEP + Ceramic Bracket.

sen to determine microleakage of the bonded specimens. This is the most commonly used method to assess microleakage of dental materials.¹⁵ It is easy to perform, fast, and economical, but the shortcoming of the technique is the subjectivity of reading the specimens.¹⁶ In our study all specimens were evaluated by the two operators at two times to evaluate measurement error. The inter- and intraexaminer Kappa scores for assessing microleakage were high; all values were greater than 0.75.

Microleakage, however, may not be similar on the other sides on a bonded tooth, although studies on restorative dentistry have assumed that one-side assessment is representative of the whole tooth.¹⁷ Airlocks in the marginal gap, leaching of water-soluble tracers during processing, and failure of only a few sections to allow interpretation of the full pattern, limit dye-penetration tests to low reproducibility and precision. It is important to note that the assessments in the present study were made by four parallel longitudinal sections through the occlusal and gingival surfaces in the bucco-lingual direction according to Arhun et al⁸ between enamel-adhesive and adhesive-bracket interfaces. Mean scores for the four occlusal sections give the occlusal microleakage score and mean scores for the gingival sections give the gingival microleakage score.

In vitro, microleakage is commonly assessed to detect bond failure at the enamel sealant interface through dye penetration. This failure can be due to polymerization shrinkage or different linear coefficients of thermal expansion from tooth hard substances and

resin materials.¹⁸ Thermal cycles are widely used to simulate temperature changes in the mouth, generating successive thermal stresses at the tooth-resin interface. In restorative dentistry, Kubo et al¹⁹ investigated the microleakage of self-etching primers after thermal and flexural load cycling and found that the marginal integrity of self-etching primers did not deteriorate even after thermal cycles (5000–10,000 cycles) and flexural loads. Similarly, several other workers have shown that an increase in the number of thermal cycles was not related to an increase in microleakage of restorations.^{18,20,21} Therefore, thermocycling was not performed in this study.

Polymerization shrinkage varies by adhesive composition, that is, percentage of filler, the diluents, or the percentage of the monomer conversion in the specific composite resin²² and curing type.²³ Polymerization shrinkage of the adhesive material may cause microleakage-promoting micro gaps between the adhesive material and the enamel surface, which may initiate microleakage and possible white-spot lesions under the bonding area.¹¹ However, from an orthodontic perspective this condition is different. Adhesives at the edges of the bracket can absorb some shrinkage,⁸ and this shrinkage can pull the bracket closer to the enamel by the free floating of the bracket. In contrast to the thick composite resin put in a prepared cavity in restorative dentistry, polymerization shrinkage and the subsequent microleakage is less of a concern in orthodontic adhesives because a thin layer is used.

Arhun et al⁸ found that microleakage scores obtained from the incisal and gingival margins of the

brackets demonstrated significant differences, implying increased microleakage on the gingival side. They interpreted these differences as related to the surface curvature anatomy, which may result in relatively thicker adhesive at the gingival margin. However, the authors did not explain which visible light-curing device was used and how. In the present study a conventional quartz tungsten halogen curing device with a 10-mm diameter light tip was used for 40 seconds from the occlusal surface.

Results of this study indicated that porcelain brackets showed statistically significantly more microleakage at the gingival side than the occlusal side in the enamel-adhesive interface. We also observed no microleakage at the occlusal sides in the adhesive-bracket interface. Our findings were similar with Arhun et al,⁸ but our interpretation was different. We thought that lower or no microleakage scores at the occlusal side than at the gingival side may be related to the curing method in that we applied light from occlusal.

The presence of resin tags prepared at the enamel surface by acid etching is an important factor to fight leakage.¹⁸ A deeper etching pattern ensures the possibility of better resin penetration, but it does not guarantee a sealant-enamel interface that is free of microleakage or better sealant retention.¹⁸ This is supported by an in vivo study where no differences were found between sealants applied over a self-etching adhesive or H₃PO₄ etched teeth after 24 months.²⁴ However, several in vitro studies do not advocate the use of self-etching adhesives on intact enamel because of significantly lower bond strengths, greater microleakage, and an etching pattern that is not deep enough to obtain good penetration of bonding resin.^{25,26} Our results were consistent with the literature for microleakage under brackets at the enamel-adhesive interface.⁸ Both metallic and ceramic brackets bonded with TSEP showed significantly higher microleakage than when the conventional acid-etch method was used.

Several studies in the literature^{27,28} indicate that ceramic brackets produce stronger bonds than the metallic orthodontic brackets. Arhun et al⁸ reported that the increased strength and difficulty in debonding for ceramic brackets may be attributed to the close adhesion of the ceramic bracket to the adhesive in the absence of microleakage. Similar to the opinion of Arhun et al,⁸ we thought incomplete polymerization of the adhesives under metallic brackets may explain this difference, because investigators^{29,30} indicated a number of factors that affect the final degree of cure of a resin. These included the chemical structure of the dimethacrylate monomer and the polymerization conditions, that is, atmosphere, temperature, light intensity, photoinitiator concentration, filler type, shade of adhesive resin, and the reflective characteristics of ad-

hesive resin bulk.³⁰ Yoon et al³¹ explained this incomplete polymerization of the cure by decreases from the top surface inward.

Further studies are necessary in orthodontics to investigate the correlations between microleakage and shear bond strength, different bonding materials, and curing devices. Moreover, a study should be designed to investigate the reason for the difference in the amount of microleakage between the gingival and occlusal sides of the orthodontic brackets.

CONCLUSIONS

- Gingival sides in all groups exhibited higher microleakage scores compared with those observed in occlusal sides for both adhesive interfaces.
- Enamel-adhesive interfaces exhibited more microleakage than did the adhesive-bracket interfaces.
- Brackets bonded with self-etching primer system revealed significantly higher microleakage at the enamel-adhesive interface of the gingival side.

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