Evaluation of Microleakage under Orthodontic Brackets Bonded with Nanocomposites

Abstract

**Background:** The aim of this study was to evaluate the microleakage value under orthodontic brackets bonded with a nano-filled composite and to compare the results with a conventional adhesive using two different bonding systems. **Materials and Methods:** Forty human premolars were used in this cross-sectional study. The samples were randomly divided into four equal groups of ten: Group I: Acid etch plus Transbond XT primer and Transbond XT adhesive, Group II: Acid etch plus Transbond XT primer and nanocomposite (Filtek Z350), Group III: Scotchbond™ Universal primer plus Transbond XT, and Group IV: Scotchbond™ and nanocomposite. Sections were prepared for microleakage evaluation at the occlusal and gingival margins. Statistical analysis was performed to compare the microleakage values among the groups using analysis of variance (ANOVA).

**Statistical Analysis:** Microleakage values were analyzed with two-way ANOVA test. Intraexaminer error was evaluated by the Kappa statistic. The level of significance was considered at $P < 0.05$.

**Results:** Gingival side displayed statistically higher microleakage ($P < 0.001$). The nanocomposite Filtek Z350 generally represented higher microleakage when compared with the Transbond XT at both occlusal and gingival sides of the brackets ($P < 0.001$). More microleakage values were observed in brackets bonded using acid etch compared with Scotchbond. Comparison of microleakage among all the four groups revealed that Group II and Group III had the most and the least microleakage values, respectively, at the enamel–adhesive interface. Microleakage values for groups bonded with nanocomposite were significantly higher. **Conclusion:** This investigation clearly reveals the outstanding superiority and efficiency of a Transbond XT adhesive combined with a Scotchbond primer over that obtained using a Filtek Z350 nanocomposite in any combination with the used primers to limit microleakage under bonded brackets.

**Keywords:** Adhesive, bonding agent, dental leakage, margin, nano

Introduction

One of the problems encountered in fixed orthodontic treatment is decalcification of enamel beneath and around the brackets.[1] The prevalence of white spot lesions at the end of fixed orthodontic treatment has been reported in up to 97% of patients.[2]

Although plaque accumulation following poor oral hygiene is the principal cause of decalcifications, etching the enamel and the type of applied sealants and composite resins thereafter for bonding the brackets also plays an important role on the exacerbation of demineralization.[3] Evaluation of the antimicrobial and anti-caries applications of nanoparticles showed that although nanotechnology can have many potential benefits, information on the long-term effectiveness of orthodontic materials using this technology is inadequate and further studies are needed in this regard.[4]

Nozari et al. conducted a study on the effect of nanoparticles on primary teeth enamel remineralization. They concluded that nano silver fluoride had a significant effect on teeth remineralization.[5]

While according to some studies measurable demineralization of the enamel may occur around orthodontic brackets even after 1 month,[6] the use of preventive methods is of high importance. In this context, microleakage beneath orthodontic brackets is of significant clinical importance. Microleakage facilitates the penetration of bacteria and fluids from the oral cavity at the enamel–adhesive interface through gap formation.[1] This penetration plays a pivotal role in producing clinical and esthetic problems such as enamel demineralization (white spot lesions), tooth

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discoloration, corrosion, and weakening of bond strength. Using of suitable sealants and composite resins is some of the efforts for overcoming the problems related to microleakage.

It has been proven that microleakage occurs due to various factors such as polymerization shrinkage of the resin, different thermal expansion of the enamel and the adhesive, and inadequate adhesion.

Numerous studies in orthodontics indicate some degree of microleakage around and beneath both orthodontic brackets and bands.

The continuous effort to develop the adhesives has resulted in introducing novel adhesive systems in orthodontics. One of these innovations are the application of nanotechnology to resin composites. Reduction of particle-size distribution and wide size distribution of fillers has resulted in a higher filler content, which causes improvement in mechanical properties. Reinforcement of tensile and compressive strengths, resistance to fracture, reduction of polymerization shrinkage, and thermal expansion are such improvements.

Despite the frequent use of nanocomposites in restorative dentistry, there is no consensus about the possible benefits of their application in bonding orthodontic brackets. Bishara et al. demonstrated that shear bond strength (SBS) of the brackets bonded with nanocomposite is not significantly different from those obtained with Transbond XT. Nevertheless, another group of investigators stated that AELITE nanocomposite had even a higher SBS than Transbond XT and they can be successfully used for bracket bonding. However, other studies showed that conventional orthodontic adhesive systems have higher values than the nanocomposites. Uysal et al. showed that Filtek Supreme Plus Universal nanocomposite and Ketac™ N100 Light-Curing Nano-Ionomer resulted in lower bond strengths than conventional adhesives.

A few investigations have been conducted regarding microleakage of nanocomposites. In a study performed by Shamaa et al., nanocomposite demonstrated a higher microleakage in comparison to Transbond XT.

While there are controversies in literature with respect to the possible use of nanocomposites as orthodontic adhesives, lack of enough scientific evidence to introduce a safer bonding composite resin against microleakage and consequent white spot lesions is obvious. Hence, the aim of this study was to test a nano-filled composite (Filtek Z350) as the orthodontic adhesive and evaluate its microleakage in comparison with a conventional adhesive with application of two different bonding systems. The null hypothesis of the study was that there is equal amount of microleakage under orthodontic brackets when using nanocomposites and conventional orthodontic adhesives.

Materials and Methods

Similar to a study by Arhun et al., a set of 40 noncarious human premolars, extracted for orthodontic purposes, were also used in this cross-sectional study. Teeth with hypoplastic enamel, caries, abrasions, attrition, restorations, cracks, or any other developmental defects were excluded from the study. The samples were stored in regularly changed distilled water after extraction, for a maximum time of 1 month. The buccal enamel surfaces were cleaned and polished with pumice paste for 10 s using a rubber prophylactic cap. They were then rinsed with a stream of water for 10 s. Before bonding the brackets, all the teeth were immersed in a 1% thymol solution for 1 week to be disinfected.

Two different enamel preparation methods were used for conditioning of enamel surfaces of the specimens. In the first method, a 37% phosphoric acid gel (Unitek, Monrovia, CA, USA) was used for enamel conditioning and Transbond XT primer (3M, Unitek, Monrovia, CA, USA) was applied as the sealant. The second method included the use of a Scotchbond™ Universal adhesive (3M ESPE, St Paul, MN, USA) as the self-etching primer. Stainless steel premolar brackets (3M Unitek, Monrovia, CA, USA) were bonded for all the teeth.

The samples were divided into four equal groups of 10 by random selection. The four groups received the following surface treatments and adhesive-application procedures:

- **Group I:** The teeth were etched with conventional 37% phosphoric acid gel for 15 s, rinsed, and then dried for 20 s with an oil-free air spray. Transbond XT primer was applied on the etched enamel surfaces, and the brackets were bonded using the Transbond XT adhesive.
- **Group II:** The same method of enamel preparation as Group I using 37% phosphoric acid gel and the Transbond XT primer was applied. Thereafter, nanocomposite Filtek Z350 × T (3M ESPE) was used as the bonding adhesive.
- **Group III:** Scotchbond™ Universal adhesive was applied for 3–5 s with a mild pressure of the brush according to the manufacturer’s instructions, followed by a gentle burst of air for 1–2 s. Then, the brackets were bonded using Transbond XT adhesive.
- **Group IV:** In this group, enamel preparation was the same as in Group III using a Scotchbond. It was then followed by applying nanocomposite Filtek Z350 × T (3M ESPE) as the adhesive.

Photopolymerization was performed using an LED light-curing unit (Bluelex, San Chong city, Taipei County, Taiwan) with a 10-mm diameter for a total of 20 s (10 s for mesial and distal sides each).

Next, thermocycling was performed at 5°C ± 2°C–55°C ± 2°C for 1000 cycles with a dwell time of 30 s and a transfer time of 5 s.
Microleakage evaluation

To prepare for dye penetration, the tooth apices were sealed with sticky wax and were rinsed in tap water and then air-dried. Nail varnish was then applied to the entire surface of the tooth, except for an area approximately 1 mm away from the brackets. The teeth were held in water as soon as the nail polish dried to minimize dehydration of the samples. They were then immersed in a 0.5% solution of basic fuchsine (0.5 g powder in 100 ml of distilled water) for 24 h at room temperature. After thorough rinsing with tap water, the superficial dye was removed with a brush and then dried. Next, the samples were embedded in epoxy resin blocks. To increase the accuracy of penetration measurements, two vertical buccolingual cuts (through the occlusal and gingival surfaces of each tooth) were made at the mesial and distal surfaces of each bonded bracket with a low-speed diamond disc (Lemgo, Germany).

Microleakage was directly measured and recorded in millimeters under a stereomicroscope (BS 3060, China-Carton Optical Industries, Pathumthani, Thailand) by direct measurement deploying the Image Analyzer Software of the stereomicroscope (×40) by a single-blinded observer.

Half of the samples were randomly examined again by the same observer after 2 weeks to measure the intraobserver error of measurements.

For each specimen, the microleakage score, either in occlusal or in gingival margins, along the enamel–adhesive interface was obtained by calculating the mean scores from the two sections as seen in Figure 1.

Statistical analysis

The collected data were subjected to statistical analysis to compare the microleakage values between groups using the two-way analysis of variance (ANOVA) test. Intraexaminer error was evaluated with the Kappa statistic. The level of significance was set at $P < 0.05$.

Results

The overall intraobserver agreement for each group was acceptable ($\kappa =0.797$).

Descriptive statistics including the mean and SD values for each of the four groups are presented in Table 1.

All groups showed some degree of microleakage. Moreover, comparisons between the occlusal and gingival sides of brackets revealed that gingival side displayed statistically higher microleakage than the occlusal side ($P < 0.001$).

The nanocomposite Filtek Z350 generally represented higher microleakage as compared with the Transbond XT at both occlusal and gingival sides of the brackets ($P < 0.001$). Higher microleakage values were observed in brackets bonded using conventional surface treatment (acid etch) as compared with universal bonding (Scotchbond) [Table 2 and Figure 2].

Comparison of microleakage among all the four groups revealed that Group II (acid etch + nanocomposite) had the highest and Group III (Scotchbond + Transbond XT composite) had the least microleakage values at the enamel–adhesive interface. Microleakage values for groups bonded with nanocomposite were significantly higher.

There was no significant interaction between the two variables (primer and the adhesive) ($P = 0.615$) [Table 2].

Discussion

Ideal marginal integrity between the tooth surface and the base of bracket is crucial both for bond strength (to decrease

| Table 1: Descriptive statistics of microleakage of different groups ($n=20$/group) |
|------------------------|------------------------|------------------------|------------------------|
| Adhesive | Bonding | Mean±SD | Occlusal | Gingival | Total |
| Transbond XT | Transbond XT | 0.127±0.07 | 0.168±0.08 | 0.147±0.07 |
| XT | Scotchbond | 0.110±0.10 | 0.149±0.09 | 0.129±0.09 |
| Total | | 0.119±0.12 | 0.158±0.12 | 0.138±0.12 |
| Filtek Z350 | Transbond XT | 0.143±0.13 | 0.188±0.16 | 0.165±0.14 |
| XT | Scotchbond | 0.130±0.10 | 0.172±0.13 | 0.151±0.09 |
| Total | | 0.136±0.19 | 0.180±0.16 | 0.158±0.14 |
| Total | Transbond XT | 0.135±0.13 | 0.178±0.15 | 0.156±0.14 |
| XT | Scotchbond | 0.120±0.14 | 0.169±0.18 | 0.140±0.15 |
| Total | | 0.127±0.15 | 0.169±0.11 | 0.148±0.16 |

Figure 1: Microleakage for enamel–adhesive interface in occlusal and gingival margins of one of our specimens

Figure 2: Comparison between bonding and adhesives using two-way analysis of variance analyses

SD: Standard deviation
Hedayati and Farjood: Microleakage with nanocomposites

Table 2: Two-way comparison of the amount of microleakage among different bonding and composite groups

|       | Occlusal |       |       | Gingival |       |       | Total   |       |
|-------|----------|-------|-------|----------|-------|-------|---------|-------|
|       | SS       | df    | P     | SS       | df    | P     | SS       | df    | P     |
| Bonding | 0.002   | 1     | <0.001 | 0.003   | 1     | <0.001 | 0.003   | 1     | <0.001 |
| Composite | 0.003   | 1     | <0.001 | 0.005   | 1     | <0.001 | 0.004   | 1     | <0.001 |
| Bonding × composite | 5.062E-5 | 1 | 0.513 | 1.563E-5 | 1 | 0.751 | 3.062E-5 | 1 | 0.605 |

P<0.05. SS: Sum of squares

bracket losses) and for a tight seal (to minimize bacterial and oral fluid passage), thus reducing white spot lesions around the bracket area.\[22-27\]

Long-term fixed orthodontic treatment is an important factor in increasing microleakage-oriented white spot lesions and caries under and around the brackets.\[23\] Hence, finding bonding materials with better adhesion and less prone to leakage at the margins is a great success in developing orthodontic adhesive materials.\[21\]

One of the newest advances in adhesive systems is the application of nanotechnology to resin composites. Numerous bonding studies have revealed an increase in bond strength through increasing adhesive filler concentration and finer particle size of the fillers.\[14-18\]

Moreover, a previous study has revealed time savings and greater simplicity of self-etch primers. The finding has resulted in steady increase in the use of these materials in orthodontic bonding.\[28\]

From this perspective, our present study aimed to investigate the efficacy of nanocomposites combined with two different enamel preparation methods in preventing microleakage beneath and around brackets.

In the same way, as other microleakage investigations, we used the dye penetration method to determine microleakage under bonded brackets. As the results of this reading procedure are subjective, 20 randomly selected specimens were measured by the same operator 2 weeks later to evaluate measurement errors.

In our study, all groups exhibited different degrees of microleakage at the tooth–adhesive interface. This could be due to polymerization shrinkage of adhesive material, thus resulting in gaps.\[19,21\]

Based on our results, it was revealed that Group III had the least microleakage, followed by Group I and Group IV. Group II exhibited the highest microleakage score at both occlusal and gingival margins.

The values were higher at gingival margins than occlusal sides. These results are in accordance with those of Ramoglu et al., who reported higher microleakage scores at gingival sides.\[29\] This may be explained with the fact that the special surface anatomy and curvature of tooth result in thicker adhesive layer at gingival margin.\[7,30\]

Nanocomposite Filtek Z350 was evaluated in this study. Our results showed that brackets bonded with nanocomposite had significantly higher microleakage than those with the conventional composite material (Transbond XT). Both groups of nanocomposites (Group II and Group IV) with different enamel treatment had higher scores for microleakage.

These results are in accordance with those of Shamaa et al.\[23\] Their study showed that brackets bonded with nanohybrid composite GrandioSO exhibit significantly higher microleakage.

Applying nanotechnology in the production of composite resins resulted in higher filler loading, which has been claimed to improve the physical properties. Nevertheless, several authors ascribed microleakage to higher filler loading and a smaller filler particle size due to a larger surface area which increases the material’s water uptake.\[31,32\]

A variety of studies have shown that lower viscosity of composites can improve adaptation and reduce microleakage.\[33-35\] Therefore, the higher microleakage of the nanocomposite used in this study in comparison to Transbond XT can be attributed to its more viscous nature. It is therefore suggested that if manufacturers design and introduce nanocomposites with appropriate viscosity, it would be more beneficial to be used as a preferred orthodontic adhesive.

Scotchbond is one type of self-etching primers. Etch and bond steps are united in such systems and the rinse step is eliminated, simplifying the whole-bonding process and reducing chair time.\[36,37\]

Cal-Neto and Miguel examined tooth surface under scanning electron microscope and stated that using self-etching systems results in a more uniform etch pattern and less enamel destruction.\[38\] Although resin tags are longer and may penetrate deeper in enamel with etch and rinse systems, the role of resin tag length in the amount of microleakage is still controversial. Some studies have shown low correlation between length of resin tags and microleakage or bond strength.\[39-41\]

The results of our study demonstrated that brackets bonded with self-etching primer (scotch bond) had significantly lower microleakage values against those with etch and rinse systems. These findings are in accordance with those of Gupta et al., who reported a lower microleakage score at the gingival side of brackets bonded with self-etching primer systems as well.\[28\] On the other hand, our results were inconsistent with those of Shamaa et al.,\[22\] who stated that brackets bonded using self-etching primers showed significantly higher microleakage values. This may
be due to the fact that conventional and self-etch groups were not matched for adhesives as Transbond XT was used with the former and nanocomposite was used with the latter.

**Clinical recommendations**

According to our findings, it seems that despite enhanced properties of nanocomposites, they may not substitute Transbond XT adhesives which are the “gold standard composite resins for bonding in orthodontics.” It is proposed that the use of a combination of self-etch primer “Scotchbond” and Transbond XT in addition to time savings in bonding procedures may be more beneficial for decreasing the side effects of marginal microleakage and subsequent discoloration or white spot lesions in long-term fixed orthodontic treatments.

Conducting further in vivo studies to evaluate marginal discoloration and/or white spot lesions is therefore recommended.

**Limitations**

Similar to other in vitro studies in the field of biomedical sciences, certain limitations are associated with our study. Simulation of oral cavity is not possible due to different conditions and variables available in the oral cavity such as the presence of saliva with wide variation of pH, enzymes, minerals, and different temperature changes. Therefore, despite many efforts to duplicate the same condition as oral cavity, certain unavoidable bias is possible for any in vitro study like ours.

**Conclusion**

Some degree of microleakage was observed in all the investigated groups.

Higher degrees of microleakage were exhibited at gingival margins as compared to occlusal margins.

This investigation clearly reveals outstanding superiority and efficiency of Transbond XT adhesive in combination with Scotchbond primer over Filtek Z350 nanocomposite with any combination of used primers in limiting microleakage under bonded brackets.

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**Conflicts of interest**

There are no conflicts of interest.

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Hedayati and Farjood: Microleakage with nanocomposites

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