MICROLEAKAGE PATTERN AT ENAMEL-ADHESIVE INTERFACE UNDER METAL BRACKETS BONDED WITH CONVENTIONAL OR NANO-ADHESIVE SYSTEMS

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ABSTRACT

Objective: This in vitro study is aimed at assessing the microleakage at the enamel-adhesive interface under metal brackets bonded with either a conventional or nano-adhesive system.

Materials & Methods: The dye penetration method was used to evaluate microleakage at the enamel-bracket interface. Twenty freshly extracted human maxillary and mandibular premolars (average age of 15.47 ± 2.18 years) were randomly divided into two groups (n = 10/group/type of bonding composite). Group 1 comprised metal brackets bonded with conventional light-cured Transbond XT (3M-Unitek). Group 2 consisted of metal brackets bonded with flowable nano-hybrid composite GrandioSO Flow (Voco-German) used in combination with a one-step self-etch dual-cured adhesive called Futurabond DC (Voco-Germany). Specimens were thermocycled, immersed in Fuchsin dye, sectioned longitudinally, and analyzed for microleakage. Microleakage of the enamel-adhesive interfaces was observed at both the occlusal and gingival margins. A statistical analysis was performed using the t-test and paired t-test.

Results: Both groups demonstrated microleakage at the enamel-adhesive interface. However, the metal brackets bonded with the nano-composite GrandioSO Flow (G2) exhibited significantly higher microleakage than those bonded with the conventional composite material (p < 0.05).

Conclusion: Flowable nanocomposites may still not be the adhesive of choice for bracket bonding due to their remarkable microleakage at the enamel-adhesive interface in comparison with the conventional light-cured Transbond XT (3M-Unitek).

Keywords: Metal bracket, nanocomposite, conventional composite, microleakage, Fuchsin stain


INTRODUCTION

Microleakage under orthodontic brackets remains a notable clinical challenge because of frequent bracket failure at the compromised enamel-bracket interface1. Enamel decalcification (white spot lesion) and tooth discoloration during orthodontic therapy are important clinical problems that result from microleakage and may display esthetic problems2. Boersma et al. reported in 2005 that up to 97% of patients treated with fixed appliances showed white spot lesions after orthodontic therapy3. Thus, the prevention of microleakage is crucial to prevent tooth decay and minimize tooth discoloration during orthodontic treatment.

Since the invention of light-cured resin composites in the 1970s, their use for bonding
orthodontic brackets has increased tremendously. The prime advantage of light-cured resin composites is their setting time, which allows for a longer working time for bracket positioning. However, polymerization shrinkage in adhesive resin composites is one of the major disadvantages. Polymerization shrinkage results in the ingress of oral fluids and microbial ingress at the enamel-adhesive interface. A path of microleakage between the adhesive and enamel leaves the potential for microbial ingress and consequent enamel decalcification.

Ramoglu et al. emphasized the importance of using adhesive materials of minimum shrinkage for bonding orthodontic brackets to prevent the development of white spot lesions. It was also claimed that decreasing the interparticle spacing improves the mechanical properties and decreases the microleakage of adhesive resin composites. Consequently, the most recently introduced nanocomposites, which have better mechanical properties and less microleakage, are now being used to manufacture resin composites instead of the previously used hybrid, microhybrid, and microfilled-type composites.

However, as the claim is still controversial, this in vitro study is aimed at comparing the amount of microleakage associated with metallic brackets bonded with a conventional light-cured resin-composite adhesive system and flowable nano-hybrid light-cured adhesive resin composite system. The null hypothesis adopted in this study was that there is no significant difference in microleakage of enamel-adhesive bracket interfaces at the occlusal and gingival margins of metallic brackets bonded with nano-hybrid and conventional adhesive systems.

**MATERIALS & METHODS**

Twenty caries-free intact human premolars, aged an average 15.47 ± 2.18 years, were readily extracted for orthodontic purposes (the patients were intimated about the process and their consent taken prior to extraction). The premolars were randomly divided into two equal groups, to be kept in regularly changed fresh water for one week after the enamel was checked under a transillumination unit (Pluraflex HL 150, Litema, GSD, Germany) for the presence of cracks and developmental defects. If defects were detected, the premolars were discarded, and a new tooth was selected and prepared for investigation. The teeth were cleaned of debris and further polished with pumice and rubber cups for 10 seconds. Both groups received the following surface treatments and adhesive-application procedures:

**Step A**

Group 1 (G1): After acid etching (conventional 35% phosphoric acid gel), 10 Mini Master metal brackets (American Orthodontics, Sheboygan, Wisconsin, USA) were bonded to the teeth with Transbond XT (3M Unitek, Monorovia, CA 91016, USA). The adhesive resin composite was cured with an LED curing unit (XH-S212, Zhengzhou XingHua Dental Equipment, Henan Province, PRC) for 20 seconds (5 seconds/margin).

Group 2 (G2): After acid etching with the self-etch Futurabond DC (1218544, Voco, Cuxhaven, Germany), 10 Mini Master metal brackets (American Orthodontics, Sheboygan, Wisconsin, USA) were bonded to the teeth with GrandioSO Flow (1222074, Voco, Cuxhaven, Germany). These materials were cured with the same LED curing unit used with Group 1 (5 seconds/margin).

**Step B**

After the brackets were bonded, thermocycling was performed at 5 ± 2°C to 55 ± 2°C for 500 cycles with a dwell time of 30 seconds and transfer time of 10 seconds.

**Step C**

Prior to the dye penetration, premolar apices were sealed with sticky wax. Moreover, specimens were coated with two consecutive layers of nail varnish up to 1 mm from bracket margins mesially and distally to prevent the other surfaces from dye penetration. The specimens were then immersed in a 0.5% basic...
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Fuchsin solution (632-99-5-Lobachemie-India) for 24 hours. After thorough rinsing with fresh water, the samples were air-dried and embedded in epoxy resin according to the manufacturer’s instructions.

**Step D**

A parallel, longitudinal section from the middle part of each premolar was cut at the occluso-buccal and occluso-lingual surfaces (20 sections/group) with a low-speed diamond saw (MICRACUT 125, Metlab Corp, USA). The sections were then examined by calibration under a stereomicroscope (Leica, Germany) at standard magnification (12.5x) by three different investigators in a blinded fashion (Figure 1 A, B).

**Step E**

The depth of dye penetration in the specimens was evaluated. Microleakage was determined by direct measurement using image analyzer software (Leica QWin 500, Germany). Each section was measured for microleakage at the occlusal and gingival levels along the enamel-adhesive interface (Figure 2). The microleakage score was obtained by separately calculating the mean occlusal and gingival microleakage scores. For intra-examiner reliability, at least three measurements were recorded for each sample.

**STATISTICAL ANALYSIS**

The enamel-adhesive interface was investigated at the gingival and occlusal sides. For each specimen, the microleakage scores of the gingival and occlusal sides were obtained by calculating the mean microleakage scores for each side measured from two sections. Collected data was subjected to statistical analysis to compare the microleakage between both test groups using the t and paired t tests (Statistical Package for Social Sciences, SPSS version 20.0, Chicago, Ill). The level of statistical significance was set at p < 0.05.

**RESULTS**

Both groups (G1, G2) displayed higher microleakage scores at the gingival sides than occlusal sides. The mean occlusal and gingival microleakage scores at the enamel-adhesive interface for both the adhesive systems (G1, G2) revealed statistically significant microleakage under the metal brackets. The nanocomposite GrandioSO Flow material generally represented higher microleakage readings, compared with the Transbond XT adhesive at the enamel-adhesive interface at the occlusal and gingival sides of the brackets (Table 1).

Statistical comparisons were made between the occlusal and gingival microleakage scores of
both the groups shown in Table 2. Both sides displayed statistically significant microleakage differences. The gingival side demonstrated statistically significant higher microleakage than the occlusal side at the enamel-adhesive interfaces (p < .05). Group 2 also displayed statistically significant higher microleakage scores than Group 1 at the gingival side between the enamel-adhesive interfaces and at both the gingival and occlusal sides. According to our findings, the null hypothesis was rejected.

Table 1. Descriptive statistics of microleakage of conventional and nano-adhesive groups (occlusally and gingivally)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Statistical evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusal side</td>
<td>G1</td>
<td>10</td>
<td>.042</td>
<td>.096</td>
<td>.000</td>
<td>0.285</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>10</td>
<td>.586</td>
<td>.450</td>
<td>.000</td>
<td>1.049</td>
</tr>
<tr>
<td>Gingival side</td>
<td>G1</td>
<td>10</td>
<td>.300</td>
<td>.285</td>
<td>.000</td>
<td>0.768</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>10</td>
<td>.908</td>
<td>.583</td>
<td>.000</td>
<td>1.778</td>
</tr>
</tbody>
</table>

G1: Conventional composite Transbond XT; G2: Nanocomposite GrandioSO Flow; N: Sample size; SD: Standard deviation; Min: Minimum; Max: Maximum; *: Significant p ≤ 0.05

Table 2. Paired sample t test between both groups

<table>
<thead>
<tr>
<th>Material</th>
<th>Paired differences</th>
<th>t</th>
<th>df</th>
<th>Significance (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>SE</td>
<td>95% confidence interval of the difference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Lower</td>
</tr>
<tr>
<td>G1 - Gingival side</td>
<td>-.608</td>
<td>.488</td>
<td>.154</td>
<td>-.957</td>
</tr>
<tr>
<td>G2 - Occlusal side</td>
<td>-.543</td>
<td>.459</td>
<td>.145</td>
<td>-.872</td>
</tr>
</tbody>
</table>

G1: Conventional composite Transbond XT; G2: Nanocomposite GrandioSO Flow; SD: Standard deviation; SE: Standard Error; p < 0.05

DISCUSSION
Assessing microleakage is considered the most common method of evaluating the sealing ability of adhesive materials. Dye penetration is the method preferred for microleakage assessment as it offers simplified digital imaging of the prepared area\textsuperscript{12}. The harsh oral environment represents an important co-determining factor in the ultimate success of any dental material, including the newly developed adhesive materials used for bracket bonding\textsuperscript{13}. Such factors are deemed the prime causes of microleakage under any type of orthodontic bracket.

Although microleakage-oriented caries is well-documented in restorative dentistry literature, the potential of caries adjacent to and under orthodontic brackets still remains an underestimated threat to permanent teeth, especially with regard to long-term fixed therapy. In the present study, the enamel-adhesive interfaces were scored separately. The enamel-adhesive interfaces are critical to the occurrence of white spot lesions and may play a significant role in bracket failure as a result of bond degradation. Numerous studies are focused largely on decalcification and white spot lesions around, not under, the brackets\textsuperscript{14}. Although the entire area around the brackets is critical, the area under the brackets also requires attention. In this study, the dye penetration method was chosen to determine microleakage of bonded specimens as the most commonly used method to assess microleakage of dental materials\textsuperscript{13, 15}. This method is easy to execute, economical, and fast, but the reading of specimens is subjective\textsuperscript{16}. Therefore, all the specimens were evaluated by the same operator at three different time periods to evaluate measurement errors.
From the previously illustrated results, both groups investigated (G1, G2) displayed dye penetration at the enamel-adhesive interface. This could most likely be due to polymerization shrinkage of the adhesive material, which would create internal stresses, resulting in microleakage and gapping at the enamel-adhesive interface. However, bonding the metallic brackets with nanocomposite flowable material to self-etched (Futurabond DC) premolar tooth surfaces (G2) displayed significantly higher microleakage values under the metallic brackets. These values were higher at the gingival sides than occlusal sides (Table 2). The results of the present study are in accordance with those of Ramoglu et al., which reported higher gingival microleakage scores than occlusal ones (Table 1). This could be explained with relation to the surface curvature anatomy, which results in thicker adhesives at the gingival margin. However, our results are different from those of Korkmaz et al. and Hamouda et al., which prove lower microleakage of nanocomposite materials.

Several factors affect the bond strength of brackets, such as the adhesive system used, composition of composites, type of photopolymerization, and exposure time. Microleakage may also impact the bond strength of brackets, but orthodontically there is no evidence for this. Though numerous studies address the effect of microleakage on the durability of bond strength, James et al. could not demonstrate any correlation between microleakage and bond strength.

Adhesive compositions of fillers and diluent concentration, and the part of monomer conversion in a composite resin result in varied polymerization shrinkage. Peutzfeldt et al. described the choice of monomer system as a significant influencing factor in composite properties, while other authors claimed the amount of fillers and their bonding to the resinous matrix to be more decisive in determining the properties of resin composites.

Although fillers in the flowable nanocomposite GrandioSO Flow (81 wt % SiO2 of 20-40 nm) are extremely small, a higher filler loading is still possible with improved physical properties, but without increased viscosity of the material. The coated surfaces of nanofillers allow cross-linkage with the resin to create a network effect within the matrix. Nevertheless, several authors reported higher filler loading and a smaller filler particle size ascribed to microleakage due to a larger surface area, which increases the material’s water uptake. Furthermore, nanocomposites contain higher amounts of low molecular weight tri-ethylene glycol dimethacrylate (TEGDMA). This exhibits a higher degree of cross-linkage and has a more rigid material due to the higher content of the double bonds. In spite of this, the elution of TEGDMA monomers could be a contributing factor to the micro-gap formation and occurrence of microleakage in the material. Our results are in accordance with those of Uysal et al., which reported that brackets bonded with self-etching primer systems revealed significantly higher microleakage at the enamel-adhesive interface at the gingival sides. This finding was explained via the higher hydrophilicity of self-etch adhesives to behave as semipermeable membranes, which allows fluid passage, significantly risking bond durability and marginal integrity.

Though the flowable nanocomposite GrandioSO Flow (1222074, Voco, Cuxhaven, Germany), a newly introduced adhesive system, is time saving, it demonstrates substantial caries incidence under bonded orthodontic brackets.

CONCLUSION

a. Microleakage was observed along both the types of adhesive systems used: GrandioSO Flow (Voco) and Transbond XT Transbond XT (3M-Unitek).

b. The gingival sides in both groups exhibited higher microleakage scores than those observed in the occlusal sides for enamel-adhesive interfaces.
c. The brackets bonded with nanocomposite system GrandioSO Flow (1222074, Voco, Cuxhaven, Germany) revealed significantly higher microleakage at the enamel-adhesive interface at the gingival sides.

d. Further efforts and initiatives should be undertaken to develop adhesive systems to prevent enamel demineralization during long-term orthodontic treatments.

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REFERENCES


