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

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ABSTRACT

Objective: This in vitro study aimed to assess the microleakage at the tooth-adhesive interface underneath metal-brackets, either bonded with a conventional or a nano-adhesive system.

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

Results: Both groups demonstrated microleakage at the adhesive-enamel interface, yet the metal-brackets bonded with the nano-composite Grandio SO Flow (G2) exhibited significantly higher microleakage values at the adhesive-enamel interface compared to brackets bonded with the conventional composite material ($p < 0.05$).

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

KEY WORDS: Metal-bracket, Nano composite, Conventional composite, Microleakage, Fuchsin stain.

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INTRODUCTION

Microleakage under orthodontic brackets remains a prominent clinical challenge because of frequent bracket failure at the compromised enamel-brackets interface[1]. Enamel decalcification (white spot lesion) and tooth discoloration during orthodontic therapy are important clinical problems resulting from microleakage, possibly displaying esthetics problems.[2] In 2005, Boersma et al.[3], reported that up to 97 % of patients treated with fixed appliances displayed white spot lesions after orthodontic therapy [3]. Therefore, the prevention of microleakage is a crucial step to prevent tooth decay besides minimizing tooth discoloration during orthodontic treatment.

Since the invention of light-cured resin composites in 1970s, the use of light-cured resin composites for bonding orthodontic brackets has increased tremendously. The main advantages of light-cured resin composites are their command setting time, allowing for longer working time during bracket positioning [4]. However, polymerization shrinkage of adhesive resin composites is one of their major disadvantages[1,5]. Polymerization shrinkage results in an ingress of oral fluids and microbes at the tooth/adhesive interface [6]. An available path of microleakage between the adhesive and enamel creates the potential for microbial ingress with consequent enamel decalcification [7].

Ramoglu et.al, emphasized the importance of using adhesive materials with a minimum amount of shrinkage for bonding orthodontic brackets, to prevent development of white spot lesions [8]. It was also claimed that decreasing the inter-particle spacing improves the mechanical properties and decreases the microleakage of resin composite adhesives. Subsequently, manufacturing of resin composites shifted from hybrids, microhybrids and microfilled types, to the most recently introduced nanocomposites, assuming better mechanical properties and less microleakage [9-11].

However, as this claim is still controversial, this in-vitro study aimed to compare the amount of microleakage associated with metallic brackets bonded with a conventional light-cured resin-composite adhesive system and a flowable nano-hybrid light-cured resin composite adhesive system. The null hypothesis adopted in this study was the presence of an insignificant difference in microleakage of enamel-adhesive-bracket interfaces, at the occlusal and gingival margins of metallic brackets bonded with nano- and conventional adhesive systems.

MATERIALS AND METHODS

Twenty caries-free intact human premolars, of average age 15.47 ± 2.18 years, readily extracted for orthodontic purposes (Acceptance was taken from the patients prior to the extraction of their teeth) were selected for this study. Premolars were randomly divided into two equal groups, to be kept in regularly-changed fresh water for one week. Afterwards, 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. Teeth were cleaned off debris and then they were further polished with pumice and rubber cups for ten 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), ten Mini Master metal-brackets (American Orthodontics, Sheboygan, Wisconsin, USA) were bonded to teeth with Transbond XT (3M Unitek, Monorovia, CA 91016, USA). The resin composite adhesive 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), ten Mini Master metal-brackets (American Orthodontics, Sheboygan, Wisconsin, USA) were bonded to the tooth with Grandio SO 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 bonding the brackets, thermocycling was performed at 5±2°C to 55± 2°C for 500 cycles with a dwell time of 30 seconds, and a transfer time of 10 seconds. **Step C:** Before dye penetration, premolar apices were sealed with sticky wax. Moreover, specimens were coated with two consecutive layers of nail varnish up to 1 mm mesially and distally from bracket margins, to prevent the other surfaces from dye penetration. Afterwards, specimens were immersed in 0.5% basic Fuchsin solution (632-99-5-Lobachemie-India) for 24 hours. After thorough rinsing with fresh water, the samples were air-dried, then they were embedded in epoxy resin blocks according to their manufacturer's instructions.

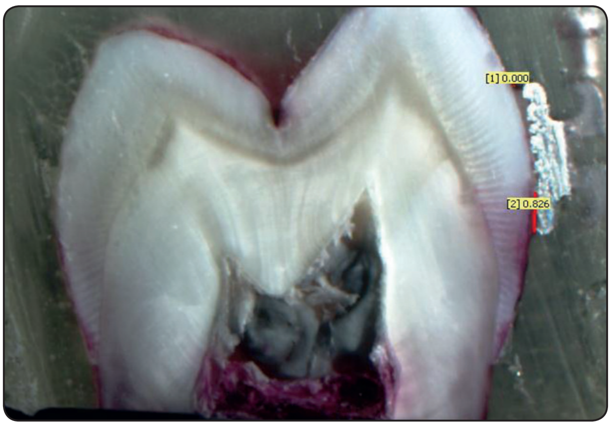

Fig. (1) A specimen with a metal bracket, demonstrating microleakage at the tooth-adhesive interface (magnification 12.5 X)

Step D: A parallel, longitudinal section of 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). All sections were examined by calibration under a stereomicroscope (Leica, Germany) at standard magnification (12.5×) by three different investigators in a blinded fashion; Fig. (1).

Step E: The depth of dye-penetration in all specimens was evaluated. Microleakage was determined by direct measurement using an image analyzer software (Leica QWin 500- Germany). Each section was measured for microleakage at the occlusal and gingival levels, along the enamel-adhesive interface Fig. (2 A, B). The microleakage score was obtained by calculating the means of occlusal and gingival microleakage measures separately. For intra-examiner reliability, an average of 3 measurements for each sample were recorded.

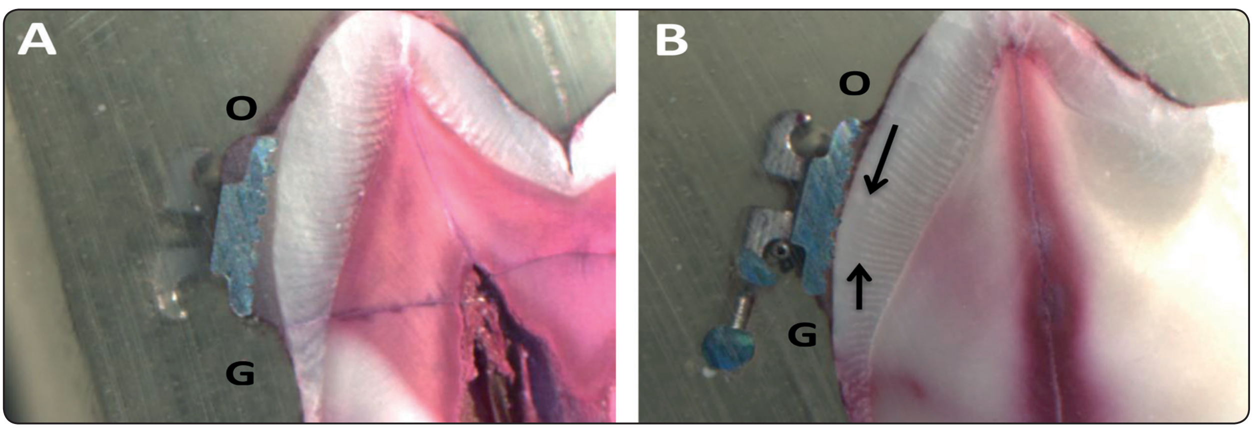

Fig. (2) Determination of microleakage at the tooth-adhesive interface measured directly using an image analyzer. A. Demonstrating 0 microleakage at the tooth-adhesive interface B. Demonstrating microleakage at the tooth-adhesive interface gingivally and occlusally

Statistical Analysis

The enamel-adhesive interface was investigated for each specimen at the gingival and occlusal sides, calculating the mean microleakage scores at two sections. Collected data were subjected to statistical analysis to compare the microleakage between both test groups using the ***t*** test and the 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) showed statistically significant microleakage values under metal brackets, being significantly higher at the gingival- than at the occlusal sides ($p < 0.05$). The Nanocomposite Grandio SO Flow material generally represented higher microleakage readings, compared with Transbond XT adhesive at the enamel-adhesive interface at both occlusal and gingival sides of the brackets, Table (1). Group 2 also, showed significantly higher microleakage values than group 1, especially at the gingival side between the tooth-adhesive interface and at both the gingival and occlusal sides. According to our findings the null hypothesis was rejected.

DISCUSSION

Microleakage assessment is considered the most common method of evaluating the sealing ability of adhesive materials. The dye penetration method, is the method preferred for microleakage assessment, as it provides an easy digital imaging of the prepared area [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[13]. Such factors are set as main causes of microleakage underneath any type of orthodontic bracket.

Although microleakage-oriented caries is a well-documented entity in the restorative dentistry literature, the potential of caries adjacent to and beneath orthodontic brackets still remains an underestimated threat to permanent teeth, especially with regard to long-term fixed therapy. In the present study adhesive-tooth interfaces was scored separately. The adhesive-tooth interface is the critical one regarding the occurrence of a white spot lesion, and may play a significant role in bracket failure as a result of bond degradation. Many studies focused mostly on decalcifications and white spot lesions around, and not underneath brackets [14].

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

Group		N	Mean	SD	Min	Max	Statistical Evaluation
Occlusal side	**G1**	10	0.11	0.09	0.000	0.29	*
	G2	10	0.81	0.40	0.000	1.05	*
Gingival side	**G1**	10	0.73	0.26	0.000	0.77	*
	G2	10	1.61	0.53	0.000	1.78	*

Abbreviations: G1*: Conventional composite Transbond XT;* G2*: Nanocomposite Grandio SO Flow. N: Sample size; SD: Standard deviation; Min: minimum; Max: maximum *: significant p ≤ 0.05.*

Although the entire area around the brackets is critical, the area underneath the brackets also needs 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 [13,15]. This method that is easy to execute, is also economical and fast, however reading of specimens is subjective[16]. Therefore, all specimens were evaluated by the same operator at three different time periods to assess measurement errors.

From the previously illustrated results, both groups investigated (G1,G2) showed dye penetration at the tooth-adhesive interface. This could be most probably due to polymerization shrinkage of the adhesive material, creating internal stresses, which resulted in microleakage and gapping at the tooth-adhesive interface [1,5]. However, bonding metallic brackets by nanocomposite flowable material to self-etched (Futurabond DC) premolar tooth surfaces (G2), displayed significantly higher microleakage values underneath metallic brackets, being higher gingivally than occlusally. The results of the present study are in accordance with those of Ramoglu et al [8] declaring higher gingival microleakage scores than to occlusal microleakage (Table 1). This could be explained, by the relation to surface curvature anatomy which results in thicker adhesives at the gingival margin [17,18]. Nevertheless, our results are different from the results declared by Korkmaz et al and Hamouda proving lower microleakage of nanocomposite materials [18,19].

Several factors affect the bond strength of brackets, such as the adhesive system used, composition of composites, type of photopolymerization, and exposure time. Although orthodontically not evidence-based, microleakage may also contribute to the bond strength of brackets. Though numerous studies address the effect of microleakage on durability of bond strength, James et al [6] and other authors could not demonstrate any correlation between microleakage and bond strength [1,5,6].

Polymerization shrinkage varied by adhesive composition of fillers and diluent concentration, as well as the part of monomer conversion in a composite resin. Where Peutzfeldt described the choice of monomer system as a quite influencing factor in composite properties [20], other authors claimed that the amount of fillers as well as its bonding to the resinous matrix are more decisive in determining properties of resin composites [21].

Although fillers in flowable nanocomposite Grandio SO 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. Coated surfaces of nano-fillers, allows cross-linkage with the resin to create a network effect within the matrix[22]. Still, several authors stated that higher filler loading and smaller filler particle size attribute to microleakage due to larger surface area, which increases water uptake of the material [23,24]. Furthermore, nanocomposites contain higher amounts of low molecular weight tri-ethylene glycol dimethacrylate (TEGDMA), showing higher degree of cross-linking and a more rigid material due to the higher content of double bonds [23,24]. Yet, a possible elution of TEGDMA monomers are contributing factors to micro-gap formation and occurrence of microleakage in the material. Our results are in accordance with Uysal et al [25] who have declared that brackets bonded with self-etching primer systems revealed significantly higher microleakage at the enamel-adhesive interface of the gingival side [25]. This finding was explained by the higher hydrophilicity of self-etch adhesives, to behave as semipermeable membranes which allows fluid passage, significantly risking bond durability and marginal integrity [25].

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

CONCLUSIONS

1- Microleakage was observed along both types of adhesive systems used; Grandio SO Flow (Voco), and Transbond XT Transbond XT (3M-Unitek).

2- Gingival sides in both groups exhibited higher microleakage scores compared with those observed in occlusal sides for enamel-adhesive interface.

3- Brackets bonded with nano-composite system, Grandio SO Flow, (1222074, Voco, Cuxhaven, Germany) revealed significantly higher microleakage at the enamel-adhesive interface of the gingival side.

4- More effort should definitely be made regarding the development of adhesive systems to prevent of enamel demineralization during long-term orthodontic treatment.

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