Microleakage under Orthodontic Brackets Using High-Intensity Curing Lights

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ABSTRACT

Objective: To compare the microleakage of the enamel-adhesive-bracket complex at the occlusal and gingival margins of brackets bonded with high-intensity light curing lights and conventional halogen lights.

Materials and Methods: Forty-five freshly extracted human maxillary premolar teeth were randomly separated into three groups of 15 teeth each. Stainless steel brackets were bonded in all groups according to the manufacturer's recommendations. Specimens (15 per group) were cured for 40 seconds with a conventional halogen light, 20 seconds with light-emitting diode (LED), and 6 seconds with plasma arc curing light (PAC). After curing, the specimens were further sealed with nail varnish, stained with 0.5% basic-fuchsine for 24 hours, sectioned and examined under a stereomicroscope, and scored for microleakage for the enamel-adhesive and bracket-adhesive interfaces from both the occlusal and gingival margins. Statistical analyses were performed using Kruskal-Wallis and Mann-Whitney *U*-tests with a Bonferroni correction.

Results: The type of light curing unit did not significantly affect the amount of microleakage at the gingival or occlusal margins of investigated interfaces ($P > .05$). The gingival sides in the LED and PAC groups exhibited higher microleakage scores compared with those observed on occlusal sides for the enamel-adhesive and adhesive-bracket interfaces. The halogen light source showed similar microleakage at the gingival and occlusal sides between both adhesive interfaces.

Conclusions: High-intensity curing units did not cause more microleakage than conventional halogen lights. This supports the use of all these curing units in routine orthodontic practice. (*Angle Orthod.* 2009;79:144–149.)

KEY WORDS: Microleakage; Light source; Halogen; LED; PAC

INTRODUCTION

A wide variety of visible light-cured orthodontic adhesives have become commercially available in orthodontics. The high early bond strength,[1] minimal extent of oxygen inhibition,[2] and extended working time for optimal bracket placement are the advantages of visible light-cured orthodontic adhesives. The major disadvantage of these adhesives is the fact that they shrink during polymerization, which causes shrinkage strain, marginal gaps, and eventually marginal leakage (microleakage) at the tooth-adhesive interface.[3]

Microgap formation between the adhesive material and the enamel surface contributes to microleakage, permitting the passage of bacteria and oral fluids, which may initiate white spot lesions under the bracket surface area.[4] In restorative dentistry, the clinical symptoms associated with the occurrence of microleakage are breakdown and discoloration of margins, secondary caries, increase in postoperative sensitivity, and pulp pathology.[5] From the orthodontic point of view, microleakage between composite-enamel and/or composite-bracket interfaces may lead to white spot lesions. Although halogen light curing units (LCUs) are very popular, they have several drawbacks. For example, halogen bulbs have a limited lifetime (40–100

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hours). Furthermore, the bulb reflector and filter degrade over time because of the high operating temperatures. This results in a reduction of the LCU's curing effectiveness over time.[6] It has also been shown that many halogen LCUs do not reach the power output claimed by their manufacturer.[7,8] This could result in inadequate polymerization, adversely affecting the adhesive performance.[8]

Alternatives to halogen technology high-intensity LCUs have been introduced in recent years, including argon lasers, plasma arc curing (PAC) lights, and solid-state light-emitting diodes (LEDs). Argon lasers provide more consistent power density over distance than halogen lights.[9] However, questions have been raised concerning the laser's efficiency in polymerization, which can compromise the composite physical properties.[10] Also, the laser's cost has been another difficulty preventing the common use of this technology.

In contrast, PAC lights have become popular because the curing time can be reduced because of their high intensity, and they are less expensive than argon laser units. PAC LCUs emit light from glowing plasma, which is composed of a gaseous mixture of ionized molecules.[11] It is claimed that PAC lights cure composite materials at a much faster rate than conventional lights because of the high light intensity and that they reduce chair time dramatically. However, polymerization with high-intensity curing units may permit little chance for the flow necessary to provide stress relief in resin-based restorative materials.[12] The manufacturers claim that these devices reduce polymerization time to 3–10 seconds and minimize polymerization shrinkage.[13]

Despite their relatively recent introduction, LEDs have become very popular for the polymerization of light-cured adhesives.[14] LED technology uses junctions of doped semiconductors to generate light.[14] At around 470 nm, the emitted light falls conveniently within the absorption spectrum of camphoroquinone.[14,15] These LCUs avoid the use of heat-generating halogen bulbs and have about 10,000 hours of life with little, if any, degradation of the output.[14] Furthermore, LED LCUs have a chargeable battery and so they are portable. In addition, manufacturers claim that the new-generation LED LUCs provide faster monomer conversion than that achieved with conventional LCUs. Speeding up the curing process, LED units may save chair time.

So far, to our knowledge, no research has compared the effect of three different LCUs (Halogen, LED, and PAC) on microleakage under orthodontic brackets. Thus, the objective of this study was to evaluate the effects of high-intensity LCUs on the microleakage of enamel-adhesive-bracket complex at the occlusal and gingival margins.

For the purposes of this study, the null hypothesis was that the type of LCU used (halogen, LED and PAC) would not affect the amount of microleakage observed beneath brackets.

MATERIALS AND METHODS

Sample Preparation

Forty-five freshly extracted human maxillary premolar teeth without caries, hypoplastic areas, cracks, or gross irregularities of the enamel structure were used in this study. Teeth were stored in distilled water solution at room temperature. Immediately before bonding, teeth were cleaned with a scaler and pumice to remove soft-tissue remnants, callus, and plaque. Teeth were randomly separated into three groups of 15 teeth each.

Specimens were prepared for bracket bonding according to the following procedures: a 37% phosphoric acid gel (3M Espe, Seefeld, Germany) 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. Subsequently, the liquid primer Transbond XT (3M Unitek, Monrovia, Calif) was applied to the etched surface. Standard edgewise premolar stainless steel brackets (3M Unitek) were bonded to tooth with Transbond XT light cure adhesive paste. Excess resin was removed with an explorer before it was polymerized and cured with the following procedures:

Group 1: One third of the samples were polymerized for 40 seconds by a halogen LCU (Hilux 350, Express Dental Products, Toronto, Ontario, Canada) with a 10-mm diameter light tip.

Group 2: Fifteen premolar teeth were cured with a LED LCU (Elipar Freelight 2, 3M Espe) for 20 seconds.

Group 3: Fifteen teeth were separated and cured with a PAC LCU (Power Pac, American Medical Technologies, Hannover, Germany) for 6 seconds.

In all groups, LCUs were applied to the brackets from the occlusal direction for standardization of short and long curing times of units. Regarding the curing units, the important parameter is the amount of light energy of appropriate wavelength emitted during irradiation. A digital curing radiometer (curing radiometer, Demetron, Danbury, Conn) was used to calibrate the output of light tips from halogen and LED LCU. Output of the PAC (Power PAC) system, which could not be measured by cure radiometer, was estimated at 1200–1500 mW/cm^{2} according to the manufacturer's data. The total light energy was calculated with the mean output values and determined to be similar in all
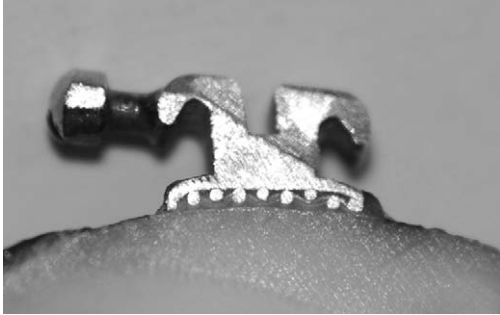
Figure 1. No microleakage under a stainless steel bracket.

Figure 2. Microleakage under a stainless steel bracket.

groups. Samples were stored in distilled water at 37°C for 24 hours before microleakage evaluation. All evaluations were done on the same day.
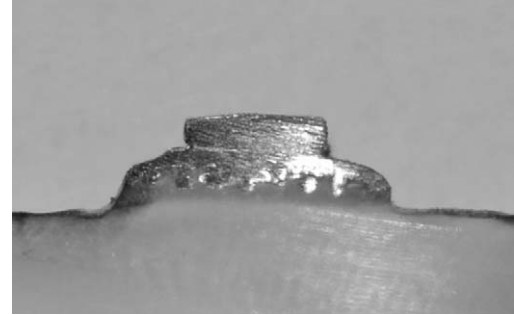
Microleakage Evaluation

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 brackets. To minimize dehydration of the specimens, the teeth were replaced in water as soon as the nail polish dried. The teeth were immersed in 0.5% solution of basic fuchsine 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 Arıkan et al[16] and Arhun et al.[17]

The specimens were evaluated under a stereomicroscope (×20 magnifications) (SZ 40, Olympus, Tokyo, Japan) for dye penetration by two operators separately. Each section was scored from both the occlusal and gingival margins of the brackets between the enamel-adhesive and the adhesive-bracket interfaces.

Microleakage was determined by direct measurement using electronic digital caliper and recording the data to the nearest 0.5 mm value (range = 0.5 to 5 millimeter). Figure 1 shows no microleakage and Figure 2 shows microleakage under the stainless steel bracket.

Statistical Analysis

For each investigated adhesive interface (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 with a Bonferroni correction. All specimens were evaluated by the two operators at two times to evaluate measurement error, and Kappa scores were estimated. The level of statistical significance was set at $P < .05$.

RESULTS

The inter- and intraexaminer Kappa scores for assessing microleakage were high; all values were greater than 0.75. 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 between enamel-adhesive and adhesive-bracket interfaces in all groups for both the gingival and occlusal sides, except for the occlusal margins of the specimens cured with the halogen unit. When the adhesive resin was cured with a PAC light source, the gingival sides exhibited higher microleakage compared with those observed on the occlusal sides in both enamel-adhesive ($P < .01$) and adhesive-bracket ($P < .05$) interfaces. When the LED LCU was used, the gingival sides exhibited higher microleakage than the occlusal sides only at the enamel-adhesive interface ($P < .05$). Curing with the halogen LCU resulted in similar microleakage at the gingival and occlusal sides between the enamel-adhesive and adhesive-bracket interfaces.

Descriptive statistical values and comparisons of the microleakage scores for three LCUs are shown in Table 2. Statistical comparisons of the microleakage scores among three groups between enamel-adhesive and adhesive-bracket interfaces indicated that the type of LCU did not significantly affect the amount of microleakage at the gingival or occlusal margins of the enamel-adhesive and adhesive-bracket interfaces ($P > .05$). Therefore, the null hypothesis could not be rejected.

Table 1. Comparison of the Microleakage Scores of Light-Curing Units (LCUs) between Occlusal and Gingival Sides for Enamel-Adhesive and Adhesive-Bracket Interfaces[a]

Interface	LCU Type	N	Occlusal		Gingival		Statistical Evaluation (Mann-Whitney U-Test)
			Mean	Standard Deviation	Mean	Standard Deviation	
Enamel-adhesive interface	Quartz tungsten halogen	15	0.000	0.000	0.117	0.186	NS P = .055
	LED	15	0.078	0.176	0.375	0.464	* P = .027
	Plasma arc	15	0.357	0.090	0.375	0.424	** P = .002
Adhesive-bracket interface	Quartz tungsten halogen	15	0.000	0.000	0.116	0.281	NS P = .238
	LED	15	0.062	0.170	0.156	0.286	NS P = .164
	Plasma arc	15	0.030	0.090	0.285	0.414	* P = .027

[a] LED indicates light-emitting diode; N, sample size; NS, not significant; * $P < .05$; ** $P < .01$.

Table 2. Comparisons of the Microleakage Scores of Different Light Curing Unit (LCUs) between Enamel-Adhesive and Adhesive-Bracket Interfaces[a]

Interface	Side	LCU Type	Mean	SD	Minimum	Maximum	Statistical Evaluation (Kruskal-Wallis Test)[a]
Enamel-adhesive interface	Occlusal	Quartz tungsten halogen	0.000	0.000	0.000	0.000	NS; P = .188
		LED	0.078	0.176	0.000	0.500	
		Plasma arc	0.036	0.091	0.000	0.250	
	Gingival	Quartz tungsten halogen	0.117	0.186	0.000	0.500	NS; P = .112
		LED	0.375	0.465	0.000	1.500	
		Plasma arc	0.375	0.425	0.000	1.500	
Adhesive-bracket interface	Occlusal	Quartz tungsten halogen	0.000	0.000	0.000	0.000	NS; P = .320
		LED	0.063	0.171	0.000	0.500	
		Plasma arc	0.036	0.091	0.000	0.250	
	Gingival	Quartz tungsten halogen	0.117	0.281	0.000	1.000	NS; P = .365
		LED	0.156	0.287	0.000	1.000	
		Plasma arc	0.286	0.414	0.000	1.500	

[a] NS indicates not significant.

DISCUSSION

Halogen LCUs are the most widely used light sources for photo-activating resin-based materials.[6,7] On the other hand, modern high-intensity curing units, such as PAC, LED, and argon, have been developed to reduce curing time.[10,11,14,15] A conventional light-curing unit with a halogen lamp requires 30–50 seconds per bracket to cure orthodontic adhesive resin. Under these conditions, the irradiation time for bonding both maxillary and mandibular arches can reach up to 10–15 minutes, and the long irradiation time may be a great drawback for both clinician and patient. Review of the literature indicated that no studies have compared the effect of three different types of light-curing units (halogen, LED, and PAC) on the microleakage under bonded brackets in a study design.

Several techniques have been introduced to assess microleakage around dental restorations. The easiest and most commonly used methodology involves exposing the samples to a dye solution and then viewing cross-sections under a light microscope.[18] To evaluate the relevance of a leakage test, the effective size of oral bacteria must be considered. Because of the range of bacteria sizes, dyes such as methylene blue and fuchsine are realistic agents to identify the presence of a clinically relevant gap.[19,20] Dye penetration was chosen for this study because it provided a simple, relatively cheap quantitative and comparable method of evaluating the performance of the various restoration techniques.[18,21] In our study all specimens were evaluated by the two operators at two times to evaluate measurement error.

Microleakage, however, may not be the same on all sides on a bonded tooth although studies on restor-

ative dentistry have assumed that one-side assessment is representative of the whole tooth.[22] Air locks in the marginal gap, leaching of water-soluble tracers during processing, and the 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 Arıkan et al[16] and Arhun et al[17] between enamel-adhesive and adhesive-bracket interfaces. The mean of the scores of the four occlusal sections gives the occlusal and the mean of the gingival scores gives 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.[23] Thermal cycles are widely used to simulate temperature changes in the mouth, generating successive thermal stresses at the tooth-resin interface. Several studies indicated that an increase in the number of thermal cycles was not related to an increase in microleakage of restorations.[24,25] Therefore, thermocycling was not performed in this study.

In the present study, we observed that microleakage on the gingival side was greater than the occlusal side when cured with PAC and LED LCUs. On the other hand, adhesive resin under brackets cured with halogen LCU displayed similar microleakage at the gingival and occlusal sides. Arhun et al[17] indicated 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 to be related to the surface curvature anatomy, which may result in relatively thicker adhesive at the gingival margin. However, the authors did not explain which LCU they used and how they used it. In the present study all curing devices were used from the occlusal surface. We thought that lower or no microleakage scores at the occlusal side compared with the gingival side may be related to the curing method that applied light from the occlusal side besides the surface curvature anatomy.

In restorative dentistry, the shrinkage of the resin caused by the rapid curing with high-intensity lights has been considered a disadvantage because of the large amount of resin placed in the cavity. Fast curing may generate excess shrinkage by permitting little opportunity for the flow of cured resin; in addition, it may result in gap formation along the resin-tooth interface, which most likely increases the potential for micro-

leakage.[26] However, from an orthodontic perspective, this condition is different. Adhesives at the edges of the bracket can absorb some shrinkage,[17] and this shrinkage can pull the bracket closer to the enamel by the bracket's free floating. In contrast to the thick composite resin put in prepared cavity in restorative dentistry, polymerization shrinkage and the subsequent microleakage is less of a concern in orthodontic adhesives because only a thin layer is used.

In this study microleakage under the bracket, which may initiate possible white spot lesions under the bonding area,[4,16,17] was not accelerated by fast curing the adhesive with PAC LCU. Also, curing the adhesive with an LED LCU unit did not affect the microleakage under brackets. Previous research on the dental application of LED units compared with halogen units has demonstrated that LED units perform as well as or better than halogen units at the same level of irradiance.[16,27,28] Moreover, some authors claim that LED curing units can reduce polymerization shrinkage and microleakage,[27] Arikan et al[17] examined the effect of LED and halogen light curing on the microleakage of bonded brackets and, in parallel with the results of the present study, they reported that both LCUs displayed similar microleakage. In the present study the null hypothesis could not be rejected because the type of LCU did not affect the amount of microleakage.

CONCLUSIONS

- Gingival sides in all groups exhibited higher microleakage scores compared with those observed in occlusal sides for both adhesive interfaces.
- The type of light-curing unit (Halogen, LED, PAC) did not significantly affect the amount of microleakage at the enamel-adhesive-bracket complex.

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