Effects of High-Intensity Curing Lights on Microleakage under Bonded Lingual Retainers

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ABSTRACT
Objective: To evaluate the effects of high-intensity light curing units (light-emitting diode [LED] and plasma arc curing [PAC]) on the microleakage of flexible spiral wire retainers (FSWRs) at the composite/enamel and composite/wire interfaces.

Materials and Methods: Forty-five human mandibular incisor teeth were separated into three groups of 15 teeth. Multistranded PentaOne wire of .0215 inch diameter was bonded to enamel and was cured with three different light curing units: a quartz-tungsten-halogen (QTH) unit and two high-intensity units (ie, LED and PAC). A conventional halogen light served as the control. Samples were sealed with nail varnish, stained with 0.5% basic fuchsine, and sectioned. Transverse sections were evaluated under a stereomicroscope and were scored for microleakage for the composite/enamel and composite/wire interfaces. Statistical analysis was performed by Kruskal-Wallis and Mann-Whitney U-tests with Bonferroni correction.

Results: Little or no microleakage was detected at the composite/enamel interface of the FSWR cured with three different light sources. However, at the composite/wire interface, statistically significant differences were found between the QTH (mean, 1.10 ± 1.05 mm) and high-intensity curing units. The PAC resulted in the greatest amount of microleakage (mean, 2.63 ± 1.49 mm), whereas no statistically significant difference was noted between the PAC and the LED (mean, 2.35 ± 1.28 mm).

Conclusion: High-intensity light curing units show statistically significant microleakage at the composite/wire interface and therefore may not be safe for use in bonding FSWRs.

KEY WORDS: Microleakage; High intensity; Photopolymerization

INTRODUCTION

Lingual retainer fabrication requires meticulous work; therefore, orthodontists prefer to use visible light cured composites over chemically cured ones. In addition to the advantages of extended working time, ease of use, and better physical properties,1-3 one of the most important tasks involved with the use of light cured composites is the choice of curing units and related curing times.

The most popular light curing unit (LCU) in dentistry has been the quartz tungsten halogen (QTH) light.4 Manufacturers have recently presented plasma arc curing (PAC) lights,5,6 argon lasers,7,8 and solid-state light-emitting diodes (LEDs)9-11 as alternatives to QTH curing units. The use of these high-intensity units has been recommended because they can enhance monomer conversion while decreasing curing time.12 According to the manufacturer instructions, these devices reduce polymerization time to 3 to 10 seconds, and they minimize polymerization shrinkage.13 Although reduced curing times offer advantages for the orthodontist and for the patient,14 rapid curing of composites may cause excessive shrinkage and gap formation along the resin/preparation interface.15,16 These gaps may cause seeping and leakage of oral fluids and bacteria between the tooth and restoration.
surface, an event that defines microleakage in dentistry.17

In restorative dentistry, microleakage may result from many factors, such as polymerization shrinkage of materials used, degradation of the particular bonding or restorative material, dissolution of linear or smear layers, and varying coefficients of thermal expansion for restorations.18 During bracket bonding in orthodontics, the composite is very thin and the composite at the edges of the bracket may absorb some shrinkage.19 Moreover, Oesterle et al14 indicated that, because the brackets are free floating, shrinkage can pull the brackets closer to the enamel. Therefore, it is believed that polymerization shrinkage and concomitant microleakage are matters of minimal concern in orthodontic applications.19 However, the composite material is used commonly in orthodontics during fabrication of the flexible spiral wire retainer (FSWR). The amount of this composite present over the retainer wire may be inversely affected by high-intensity light curing and potential gaps at the composite/enamel and composite/wire interfaces and may cause failure of FSWRs.

In operative dentistry, clinical symptoms associated with the occurrence of microleakage include breakdown and discoloration of margins, secondary caries, increased postoperative sensitivity, and pulp pathology.20 From the orthodontic point of view, microleakage between composite and enamel can cause white spot lesions, which could cause lingual retainer failure or could result in their removal. On the other hand, polymerization shrinkage and concomitant microleakage can trigger the most common lingual retainer failure type, that is, detachment at the composite/wire interface.21 This is said to be the result of insufficient composite over the wire and material loss due to abrasion.22,23

As a result, the microleakage beneath the composite is particularly important in orthodontics, especially for lingual retainer adhesives, because they are exposed to the oral cavity and are intended to serve in the mouth for a long time. LCUs differ in radiance, and it has been shown that radiant exposure has a significant effect on microleakage.15 So far, no research has reported on the effects of high-intensity LCUs on microleakage of FSWRs.

Therefore, the aim of this in vitro study was to measure and compare the microleakage between the composite/enamel and composite/wire interfaces of FSWRs that are bonded with two high-intensity LCUs (LED and PAC) and a conventional QTH light. For the purposes of this study, the null hypothesis assumed that the type of LCU used would not affect the microleakage that occurs at the composite/enamel and composite/wire interfaces.

MATERIALS AND METHODS

Sample Preparation

A total of 45 human mandibular incisor teeth, extracted for periodontal reasons, were collected over a 1-month period. Exclusion criteria included caries, cracks, developmental defects, and restorations. Soft tissue remnants were removed with a scaler, and teeth were stored in distilled water before they were randomly divided into three groups of 15 teeth.

Multistranded PentaOne wire (Masel Orthodontics, Bristol, Pa, USA) of 0.0215 inch diameter was used in all groups. Wires were cut into 20 mm lengths to ensure standardization, and the wires were bent to fit the lingual curvature of incisor teeth.

Before composite was placed, teeth were prepared according to the protocol suggested by the manufacturer (ie, cleaned with nonfluoridated pumice and rubber cups, acid etched [3M Dental Products, St Paul, Minn, USA] for 15 seconds, rinsed with water, and air dried). Transbond-XT primer (3M Unitek, Monrovia, Calif, USA) was applied to the etched surface as a thin uniform coat and was not cured.

To ensure stability during placement and contouring, the composite teeth were placed over silicone putty compound, and care was taken to thoroughly inspect the bonding area. Wires that were 20 millimeters in length were bonded to the lingual surfaces from the middle portion. While samples were prepared, care was taken to shape the bulk of the composite 4 mm in diameter and to ensure 1 mm of composite thickness over the wire.24 However, for ethical concerns, smaller and larger samples were included in the study.

Transbond-LR (3M Unitek) composite was applied and cured with one of the following LCUs at the following curing times, as suggested by manufacturers:

- Group 1 (Control): QTH (Hilux 350; Express Dental Products, Toronto, Ontario, Canada) for 15 seconds
- Group 2: LED (Elipar FreeLight 2; 3M ESPE, Seefeld, Germany) for 3 seconds
- Group 3: PAC (Power Pac; American Medical Technologies, Hannover, Germany) for 3 seconds

Microleakage Evaluation

Prior to dye penetration, the apices were sealed with sticky wax, rinsed in tap water, and air dried, and nail varnish was applied to the entire surface of the tooth, except for the area approximately 1 mm away from the composite bulk. To minimize dehydration of the bulk, the teeth were put into water as soon as the nail polish had dried. The specimens were immersed in 0.5% solution of basic fuchsin for 24 hours at room temperature. After they had been removed from the solution,
Figure 1. Microleakage between (A) composite/enamel and (B) composite/wire interfaces.

The teeth were rinsed in tap water, and the superficial dye was removed with a brush and dried.

The composite bulk was sectioned in a transverse plane (parallel to the lingual retainer wire) just above the wire with a low-speed water-cooled diamond. First, specimens were evaluated under a stereomicroscope (20× magnification) (SZ 40; Olympus, Tokyo, Japan) for dye penetration along the composite/enamel interface at the mesial and distal borders. Then, lingual retainers were gently removed from the restoration, and dye penetration at the composite/wire interface to the mesial and distal borders was evaluated under a stereomicroscope (Figure 1). Microleakage was assessed by direct measurement with an electronic digital caliper to the nearest value as a range between 0.5 and 5 millimeters, and the data were recorded.

Statistical Analysis

For each composite interface (composite/enamel or composite/wire), the microleakage score was obtained by calculating the mesial and distal microleakage scores. After the mesial and distal leakage was statistically evaluated, the score for each composite and interface was obtained by calculating the mean of the mesial and distal microleakage scores. The Shapiro-Wilks normality test and the Levene variance homogeneity test were applied to the microleakage data. The data did not show normal distribution, and no homogeneity of variances was observed between groups. Thus, statistical evaluation of microleakage values between test groups was performed with Kruskal-Wallis and Mann-Whitney U-tests with Bonferroni correction. Intraexaminer and interexaminer method error was evaluated by the kappa test. The level of significance was set at $P < .05$.

RESULTS

Intraexaminer and interexaminer kappa scores for assessment of microleakage were high, with all values exceeding 0.8.

Comparison of the mesial and distal microleakage scores for all specimens showed no statistically significant side differences ($P > .05$). Thus, the mesial and distal microleakage scores for each specimen were pooled, and the microleakage scores for each LCU and interface were obtained by calculating the mean of the mesial and distal microleakage scores.

Composite/Enamel Interface

Descriptive statistics and comparisons of microleakage between the enamel and adhesive interfaces of the three LCU groups are shown in Table 1. Little or no microleakage was observed for the three LCUs, and the differences were not statistically significant ($P > .05$). Therefore, the first portion of the null hypothesis failed to be rejected.

Composite/Wire Interface

Descriptive statistics and the results of statistical tests for microleakage at the composite/wire interface are shown in Table 2. Statistically significant differences were noted between Groups 1 and 2 ($P < .05$) and Groups 1 and 3 ($P < .01$). However, no statistically significant difference was detected between Groups 2 and 3 ($P > .05$). Comparison of the results showed the least microleakage with QTH (mean, 1.10 ± 1.05 mm) and the greatest microleakage with PAC (mean, 2.63 ± 1.49 mm). Therefore, the second portion of the null hypothesis was rejected.

DISCUSSION

Light-activated composites are now the material of choice for most orthodontists, and selection of these
materials is important. Until recently, QTH LCUs were the most popular LCUs in dentistry, but these units have drawbacks such as limited light power output when compared with consumed electric power, degradation of components, and a short lifetime. Moreover, it has been shown that halogen curing lights deliver an inadequate light density. With the introduction of LEDs in 1995, these drawbacks were thought to be overcome. The longer lifetimes and more consistent light output with LEDs compared with halogens show promise for their use in orthodontics. According to Usamez et al, another concern is the reduced curing time. Curing for 20 seconds with an LED yields similar results to curing for 40 seconds with a QTH. The advantages and disadvantages of these LCUs over others have led to a research focus on their in vitro performance. In this study, investigators aimed to evaluate microleakage in and around bonded lingual retainers, while using the same orthodontic composite cured with different light sources.

Several techniques have been introduced to assess microleakage around dental restorations. The easiest and most commonly used method involves exposure of the samples to a dye solution before cross sections are viewed under a light microscope. If the relevance of a leakage test is to be evaluated, the effective size of oral bacteria must be considered. Because of the range of bacteria sizes, dyes such as methylene blue and fuchsin are realistic agents to use for identifying a range of bacteria sizes, dyes such as methylene blue of oral bacteria must be considered. Because of the of a leakage test is to be evaluated, the effective size of oral bacteria must be considered. Because of the range of bacteria sizes, dyes such as methylene blue and fuchsin are realistic agents to use for identifying the presence of a clinically relevant gap. Dye penetration was chosen for this study because it provided a simple, relatively cheap quantitative and comparable method of evaluating the microleakage of lingual retainer composite through the use of various LCUs. In the present study, all specimens were evaluated by two operators at two different times so measurement error could be evaluated. Interexaminer and intraexaminer kappa scores for assessment of microleakage were high, with all values greater than 0.80. However, it is important to note that assessment was performed only at the mesial and distal aspects of each tooth. These sites were selected because they were readily identifiable on each specimen.

The wire of choice for this testing procedure was 0.0215 inch PentaOne. Today, this wire is most commonly used in orthodontics for lingual retainer fabrication, and a study by Bearn et al showed that a diameter increase from 0.0175 inch to 0.0215 inch increased the force required to pull out the wire from the composite.

The match between the wavelength of the LCU and the required wavelength for polymerization of adhesives is another consideration for light-activated adhesives. In orthodontics, this was not thought to be a major concern because the common photoinitiator, camphorquinone, whose initiation wavelength is 470 to 480 nm, is the most common filter for most lights. Therefore, Transbond-LR, which is a specially manufactured composite for lingual retainers, was thought to polymerize in these wavelengths with all LCUs used in this study. All specimens were prepared by the same investigator, and care was taken to get 1 mm adhesive thickness over the wire.

In this study, curing times were chosen according to the manufacturer’s instructions. Usamez et al showed that curing Transbond-LR for 6 to 9 seconds with PAC and for 40 seconds with an LED yielded statistically similar results when the degree of conversion was taken into account. Besides these results, curing for 3 seconds with a PAC produced statistically similar direct cure (DC) values compared with conventional halogen lights used for 40 seconds. Investigators thought that, in keeping with the results of previous studies, increased curing times achieved with the PAC may promote microleakage.

From this perspective, lingual retainer composites can be used as restorative materials more often than composites under a bracket, and this bulk of composite is more prone to polymerization shrinkage and gaps between the teeth and the adhesive. At the same time, these gaps may be the reason for microleakage. However, results of this study showed no statistically significant microleakage between enamel and adhesive with either of the LCUs used; thus, the total null hypothesis of this study failed to be rejected. This finding is consistent with restorative dentistry studies that showed no significant difference in microleakage between the enamel and composite interfaces when different LCUs were used.

From another perspective, according to the results of this investigation, statistically significant differences for microleakage at the composite/wire interface were noted among QTH and the other two high-intensity LCUs. Thus, the null hypothesis that assumed that the type of LCU used would not affect the microleakage between composite/wire interfaces was rejected.

In the literature, it is clearly stated that the most common failure type for lingual retainers is detachment at the wire/adhesive interface. According to the results of this study, statistically significant microleakage at this interface may be interpreted as a factor for failure. Higher scores were recorded for the PAC light source, and PAC results were comparable with those of LED LCUs.

CONCLUSIONS

- Little or no microleakage occurs at the composite/enamel interface with high-intensity LCUs.
- High-intensity LCUs allow more microleakage at the
REFERENCES