Effects of high-intensity curing lights on microleakage under orthodontic bands

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Introduction: Our objective was to compare the effects of 3 light-curing units (LCUs) (quartz-tungsten-halogen [QTH], light-emitting diode [LED], and plasma-arc curing [PAC]) on the microleakage patterns of a polyacid-modified composite (PAMC) for band cementation between the cement-enamel and the cement-band interfaces from the buccal, lingual, occlusal, and gingival margins. Methods: Sixty freshly extracted third molars were randomly divided into 3 groups of 20 teeth each. Microetched molar bands were cemented in all groups with the PAMC (Ultra Band-Lok, Reliance Orthodontic Products, Itasca, Ill) and cured for 30 seconds with the QTH (Hilux 350, Express Dental Products, Toronto, Ontario, Canada), for 20 seconds with the LED (Elipar Freelight 2, 3M Espe, Seefeld, Germany), or for 6 seconds with the PAC (Power-Pac, American Medical Technologies, Hannover, Germany). A dye penetration method was used for microleakage evaluation. Microleakage was determined with a stereomicroscope for the cement-band and cement-enamel interfaces from the buccal and lingual sides at the occlusal and gingival margins. Statistical analyses were performed with the Kruskal-Wallis and Mann-Whitney U tests. The level of significance was set at \( P < 0.05 \). Results: The gingival sides in the LED and PAC groups had higher microleakage scores compared with those observed on the occlusal sides at both the cement-band and cement-enamel interfaces. The buccal sides had similar microleakage values compared with those on the lingual sides for the cement-enamel and cement-band interfaces in all LCU types. Statistical comparisons showed that there were statistically significant differences among the investigated LCUs at the cement-enamel interface \( (P < 0.05) \). Post hoc comparisons showed statistically significant microleakage differences between the PAC (median, 0.950 mm), the QTH (median, 0.383 mm) \( (P < 0.01) \), and the PAC and the LED (median, 0.558 mm) \( (P < 0.05) \) LCUs at the cement-enamel interfaces. Conclusions: The high-intensity curing device PAC is associated with more microleakage than the LED and QTH at the cement-enamel interface. (Am J Orthod Dentofacial Orthop 2010;138:201-7)
orthodontic point of view, one can assume that demineralization areas at and under the cement or enamel can occur because of microleakage.

The latest materials developed for cementing orthodontic bands are polyacid-modified composite (PAMC) resins. Other dental materials have been used as orthodontic cements over the years, but interest has now focused on resin-based materials. Williams et al investigated the effectiveness of a conventional glass poly(alkenoate) cement and PAMC to retain orthodontic bands and found no significant differences in the in-vitro median force to deband or the in-vivo band failure rates between investigated materials.

Uysal et al compared the microleakage patterns of conventional glass ionomer cement, resin-modified glass ionomer cement, and PAMC for band cementation and found that teeth banded with resin-modified glass ionomer cement and PAMC had similar microleakage scores; both had statistically less leakage than did the conventional glass ionomer cement.

In the orthodontic literature, the effects of different LCUs (QTH, LED, and PAC) on microleakage under lingual retainer adhesives and orthodontic brackets were investigated, but, so far to our knowledge, no study has compared the effect of these 3 LCUs on microleakage under orthodontic bands. Thus, the objective of this study was to compare the effects of 3 LCUs (QTH, LED, and PAC) on the microleakage patterns of a PAMC for band cementation at the cement-enamel and the cement-band interfaces from the buccal and lingual sides at the occlusal and gingival margins.

In this study, the null hypothesis assumed that the type of LCU (QTH, LED, or PAC) would not affect the amount of microleakage observed under the orthodontic bands.

MATERIAL AND METHODS

Sixty caries-free extracted mandibular third molars were collected and stored in distilled water in a refrigerator after decontamination in 0.5% chloramine. The teeth were randomly divided into 3 groups of 20 teeth each.

The teeth were then cleaned with pumice, rinsed in distilled water, and dried thoroughly in a stream of air. Because there are no bands for third molars, mandibular permanent first molar bands with microetched fitting surfaces (G&H Wire, Greenwood, Ind) were used. A band was selected and adapted optimally to the crown of each tooth. The selected bands were cemented to the teeth with Ultra Band-Lok (Reliance Orthodontic Products, Itasca, Ill) light-cure band adhesive paste. After band placement, excess cement was removed with dry cotton rolls and light-cured with the following procedures according to manufacturers’ instructions.

Group 1: the 20 teeth were polymerized for 30 seconds with a QTH LCU (Hilux 350, Express Dental Products, Toronto, Canada) with a 10-mm diameter light tip.
Group 2: the 20 teeth were cured with an LED LCU (Elipar Freelight 2, 3M Espe, Seefeld, Germany) for 20 seconds.
Group 3: the 20 teeth were cured with a PAC LCU (Power Pac, American Medical Technologies, Hanover, Germany) for 6 seconds.

In all groups, the LCUs were applied to the bands from the occlusal direction according to manufacturers’ recommendations. To standardize the specimen preparations, band selection and cementation were done by 1 operator (S.I.R.). All specimens were then placed in distilled water for 24 hours before measuring the microleakage.

For the microleakage evaluation and before dye penetration, the tooth apices were sealed with sticky wax. After that, the teeth were 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 from the bands (Fig 1). 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 removal from the solution, the teeth were rinsed in tap water, and the superficial dye was removed with a brush; the teeth were dried and embedded in self-curing acrylic up to the occlusal surface of the band (Fig 2). First, all teeth were separated into 2 parts in the mesiodistal direction (Fig 3). Four parallel longitudinal sections from the middle of the molars were made at the occlusal and gingival margins at buccal and lingual sides with a low-speed diamond saw (Isomet, Buehler, Lake Bluff, Ill) in the bucconlingual direction according to the methods of Arikan et al and Arhun et al for the evaluation of microleakage under orthodontic brackets.

The specimens were evaluated first under a stereomicroscope (20 times magnification) (SZ 40, Olympus, Tokyo, Japan) for dye penetration along the cement-band interface. Then the band materials were gently removed from the cement, and the dye penetration at the cement-enamel interface was also evaluated under a stereomicroscope. Two assessors (M.U. and H.E) blinded to the LCU type evaluated the specimens.

To determine the amount of microleakage, an electronic digital caliper was used for measuring the distance that the dye penetrated along the cement-band and cement-enamel interfaces on the longitudinal sections; the data were recorded to the nearest 0.5 mm.
Each section was scored from the occlusal, gingival, buccal, and lingual margins of the bands at the cement-band and cement-enamel interfaces.

**Statistical analysis**

For the cement-band and cement-enamel interfaces, the microleakage score was obtained by calculating the mean of the 4 parallel longitudinal sections of the occlusal, gingival, buccal, and lingual microleakage scores.

The Shapiro-Wilks normality test and the Levene variance homogeneity test were applied to the microleakage data. The data showed nonnormal distribution, and there was no homogeneity of variances among the groups. Thus, the microleakage values between test groups were statistically evaluated by using nonparametric tests (Kruskal-Wallis and Mann-Whitney U tests). Intraexaminer and interexaminer method errors were evaluated with the kappa test. The level of significance was set at $P < 0.05$.

**RESULTS**

The intraexaminer and interexaminer kappa scores for microleakage at the buccal and lingual sides were high, with all values greater than 0.75.

Comparisons of the microleakage scores of PAMC under the orthodontic bands between the occlusal and gingival margins for the cement-band and cement-enamel interfaces at the buccal and lingual sides are shown in Table 1. The gingival sides in all PAC and LED groups had higher microleakage scores compared with those observed on the occlusal sides at both cement-band and cement-enamel interfaces. At the buccal sides, except for microleakage at the cement-band interface cured by the QTH light, statistically significant differences were found between the occlusal and gingival margins’ microleakage scores. The highest statistically significant occlusal-gingival leakage differences were observed with the LED curing unit at the cement-enamel interfaces (occlusal microleakage median, 0.250 mm; gingival microleakage median, 0.875 mm) ($P < 0.01$). No statistically significant occlusal-lingual microleakage differences were determined at the lingual side between the cement-band and cement-enamel interfaces for any LCU type ($P > 0.05$).
Statistical comparisons of buccal and lingual microleakage scores for all specimens showed no significant side differences ($P > 0.05$). Thus, the buccal and lingual microleakage scores for each specimen were pooled, and the microleakage scores for each LCU under the orthodontic bands were obtained by calculating the means of the buccal and lingual microleakage scores.

Descriptive statistics and comparisons of the LCUs for evaluation of microleakage under orthodontic bands, and between the cement-band and cement-enamel interfaces are shown in Table II. Statistical comparisons of the LCUs showed that significant differences were observed only between the cement-enamel interface ($P < 0.05$). Therefore, the null hypothesis was rejected. Post hoc comparisons showed statistically significant microleakage differences between the PAC (median, 0.950 mm), the QTH (median, 0.383 mm) ($P < 0.01$), and the PAC and LED (median, 0.558 mm) ($P < 0.05$) LCUs at the cement-enamel interfaces.

**DISCUSSION**

A review of the orthodontic literature indicated that no researchers have investigated and compared the effects of high-intensity curing lights on microleakage at the enamel-cement-band interfaces of orthodontic bands with microetched fitting surfaces cemented with PAMC. Microetched bands were used to simulate contemporary clinical practices, because this surface treatment has been shown to improve bond strength$^{12}$ and reduce the clinical failure rate$^{17}$ compared with untreated bands.

Several techniques have been introduced to assess microleakage around dental restorations. Dye penetration is a common methodology in restorative dentistry$^{18,19}$ and also in orthodontics$^{13-15,17,20}$ because it is a simple, relatively cheap, quantitative, and comparable method of evaluating the performance of the various techniques.$^{18}$ This methodology involves exposure of 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 fuchsin are realistic agents to determine the sealing ability of the tested material.$^{19}$ In our study, all specimens were evaluated by 2 operators twice to determine measurement error. Gillgrass et al$^{20}$ assessed each tooth at the midbuccal aspect. They choose this site because it was readily identifiable on each specimen and bands often loosen at this site, probably because of masticatory loading over the welded buccal attachments.$^{20}$ However, our microleakage assessments were made with 4 parallel longitudinal sections in the buccolingual direction according to methods of Arikan et al$^{15}$ and
Table I. Occlusal and gingival marginal microleakage comparisons of PAMC under orthodontic bands cured with different light sources between the cement-enamel and cement-band interfaces at the buccal and lingual sides

<table>
<thead>
<tr>
<th>Side</th>
<th>Interface</th>
<th>Curing unit</th>
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<th>gingival Median</th>
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<td>0.750</td>
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<tr>
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<tr>
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<td></td>
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</tr>
<tr>
<td></td>
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<td>0.375</td>
<td>0.250</td>
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</tbody>
</table>

NS, Not significant; *$P < 0.05; †P < 0.01.$
PAC, Plasma-arc curing light; LED, light-emitting diode; QTH, quartz-tungsten-halogen light.

Arhun et al\textsuperscript{16} for evaluation of microleakage under orthodontic brackets. Moreover, our assessments were made at both the lingual and buccal sides at the cement-enamel and cement-band interfaces.

In the literature, various failure sides for bands were reported.\textsuperscript{21-23} Millett et al\textsuperscript{23} indicated that band failures of teeth cemented with modified composite occurred predominantly at the enamel-cement interface, with failures at the cement-band interface also observed. From a microleakage point of view, our evaluations were performed for PAMC at the 2 interfaces: cement-band and cement-enamel. Microleakage at the cement-band interface might play a role in band failure caused by adhesion degradation. However, the cement-enamel interface is more critical because it can also cause white spot lesions.\textsuperscript{15}

We observed that all microleakage values on the gingival side were greater than on the occlusal side when cured with PAC and LED LCUs. On the other hand, PAMC under bands cured with the QTH LCU had different microleakage scores at the gingival and occlusal sides for the cement-enamel interface. Arhun et al\textsuperscript{16} indicated that microleakage scores obtained from the incisal and gingival margins of the brackets had significant differences, implying increased microleakage on the gingival side. They related these differences to the surface curvature anatomy, which can result in relatively thicker adhesive at the gingival margin. In this study, all curing devices were used from the occlusal surface according to the manufacturers’ instructions. We thought that generally lower microleakage scores at the occlusal side than the gingival might be related to the direction of the curing light, in addition to surface curvature anatomy.

Choi et al\textsuperscript{24} indicated that the contraction stress generated during placement of a resin-based composite contributes significantly to early marginal leakage, and this stress was significantly absorbed and relieved by applying the adhesive more thickly. Because the buccal and lingual cement thicknesses between the band and enamel were dissimilar, both the buccal and lingual sides were studied to evaluate the possible effects of cement thickness on marginal leakage.\textsuperscript{25} However, according to our findings, no statistically significant difference was found, and we observed similar microleakage scores at the buccal and lingual sides for all specimens at the enamel-cement and enamel-band interfaces.

In restorative dentistry, shrinkage of the resin caused by rapid curing with high-intensity lights has been considered a disadvantage because of the large amount of resin placed in the cavity. Fast curing might cause excessive shrinkage by permitting little opportunity for the cured resin to flow and result in gap formation along the resin-tooth interface; this most likely increases the potential for microleakage.\textsuperscript{26} In orthodontics, this condition is different, because applications usually involve thin layers of adhesives and lack areas of bulk material that seem to favor chemical cure systems. Orthodontic bands, however, are susceptible to areas of variable cement thickness and are a greater barrier to irradiation than brackets.\textsuperscript{13,25} In our study, statistical analysis indicated that the type of LCU affects the amount of microleakage at the
cement-enamel interface (P < 0.05). Thus, the null hypothesis—\( H_0 \)—that the type of LCU used (QTH, LED, or PAC) would not affect the amount of microleakage observed under orthodontic bands—was rejected. Microleakage under the bands at the cement-enamel interface that could cause demineralization under the banded area was accelerated by fast curing of the cement with the PAC LCU (\( P < 0.01 \)) (PAC median, 0.950 mm; QTH median, 0.383 mm).9,15,16 But curing the adhesive with the LED LCU unit did not affect microleakage under the bands. Previous studies on dental applications of LED units compared with QTH units demonstrated that LED units perform as well as or better than QTH units at the same level of irradiance.16,27 Moreover, some authors claim that LED curing units can reduce polymerization shrinkage and microleakage.27 Consistent with our findings, Arikan et al15 examined the effect of LED and QTH lights on the microleakage under bonded brackets and reported that both LCUs had similar microleakage values.

Usumez et al28 indicated that several factors can affect the final degree of cure of resin-based materials and the correlations with microleakage. These included the chemical structure of the dimethacrylate monomer and the polymerization conditions: atmosphere, temperature, light intensity, photo-initiator concentration, filler type, shade of adhesive resin, and the reflective characteristics of adhesive resin bulk.28 Further studies are necessary in orthodontics to investigate the correlations between microleakage and shear bond strength, and various bonding materials and curing devices.

CONCLUSIONS

Within the limitations of an in-vitro study, the following conclusions were reached.

1. PAC and LED LCUs had higher microleakage scores at the gingival margins of the bands on both the buccal and lingual sides, but the scores were not statistically significant for the occlusal margin on the lingual side.

2. The buccal sides in all groups had similar microleakage scores to the lingual sides for both the cement-enamel and cement-band interfaces.

3. Bands cemented with PAMC with fast-curing PAC had significantly higher microleakage scores than did the LED and QTH LCUs at the cement-enamel interface.

We thank UMG Uysal Medical (Istanbul, Turkey) and G&H Wire for their providing the molar bands in this project.

REFERENCES


9. James JW, Miller BH, English JD, Tadlock LP, Buschang PH. Effects of high-speed curing devices on shear bond strength and

<table>
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<th>Interface</th>
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<th>Median (mm)</th>
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NS, Not significant; *P <0.05; †P <0.01.

PAC, Plasma-arc curing light; LED, light-emitting diode; QTH, quartz-tungsten-halogen light.