The Online
ANGLE ORTHODONTIST
An International Journal of Orthodontics and Dentofacial Orthopedics
78th Anniversary 1930-2008

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TABLE OF CONTENTS

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doi: 10.2319/110905-392
***The Angle Orthodontist:* Vol. 76, No. 6, pp. 1035–1040.**

Microleakage beneath Ceramic and Metal Brackets Photopolymerized with LED or Conventional Light Curing Units

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ABSTRACT

Objective: To test the null hypotheses that (1) the type of light curing unit used (quartz-tungsten-halogen [QTH] or light-emitting diode [LED]) would not affect the amount of microleakage observed beneath brackets, and (2) the bracket type used (ceramic or metal) would not influence the amount of microleakage observed beneath brackets.

Materials and Methods: 40 freshly-extracted human premolars were randomly assigned into 4 bonding groups (n = 10/group): group 1, metal bracket + LED-cured Transbond XT; group 2, ceramic bracket + LED-cured Transbond XT; group 3, metal bracket + QTH-cured Transbond XT; and group 4, ceramic bracket + QTH-cured Transbond XT. The teeth were kept in distilled water for 1 month, and thereafter subjected to 500 thermal cycles. Then, specimens were sealed with nail varnish, stained with 0.5% basic fuchsin for 24 hours, sectioned, and photographed under a stereomicroscope. Microleakage was scored with regard to the adhesive-tooth interface and the bracket-adhesive interface at both incisal and gingival margins. Statistical analysis was accomplished by Kruskal-Wallis and Mann-Whitney *U*-tests with Bonferroni correction.

Results: Microleakage was observed in all groups. When an LED curing unit was used for adhesive polymerization, ceramic brackets displayed significantly less microleakage than metal brackets in both tooth-adhesive and bracket-adhesive interfaces. When a QTH curing unit was used, ceramic brackets displayed significantly less microleakage than metal brackets in the bracket-adhesive interface in both gingival and incisal margins.

Conclusions: Ceramic brackets cured with LED units were the best combination, demonstrating the lowest microleakage scores.

KEY WORDS: Ceramic bracket, Metal bracket, Microleakage, LED curing, Photopolymerization.

Accepted: December 2005. Submitted: November 2005

INTRODUCTION Return to TOC

In orthodontics, bonding with light-cured adhesive resins is popular because the extended working time and precise bracket placement can only be accomplished with "on-demand polymerization." Light-curing units (LCUs), therefore, have become an important part of the orthodontist's' armamentarium. To date, the most popular light-curing unit has been the quartz-tungsten-halogen (QTH)–based unit.[1] In these LCUs, halogen bulbs generate light when electric energy heats a small tungsten filament to high temperatures. Selective filters screen the wavelengths so that only blue light is emitted.[2]

Despite their popularity, QTH units have several shortcomings. First, halogen bulbs have a limited effective lifetime of approximately 40–100 hours.[3] In addition, their bulbs, reflectors, and filters degrade over time because of the large quantity of heat produced during duty cycles.[3] This results in a reduction of curing effectiveness. To overcome drawbacks of QTH units, Mills et al[4] proposed the use of solid-state light-emitting diodes (LEDs) for the polymerization of light-cured adhesives.[1] LED technology uses junctions of doped semiconductors to generate light. These units avoid the use of heat-generating halogen bulbs and have about 10,000 hours of life with little if any degradation of the output.[1,5] Furthermore, LED units are portable and are resistant to shock and vibration.

There has been an increasing interest in LED units because of their longer life span and consistent light output. In addition, manufacturers claim that new generation LED units provide faster monomer conversion than that achieved with conventional LCUs. By speeding up the curing process, LED units may save chair time for doctor and patient.

On the other hand, speeding the curing process may well result in an increase in the amount of microleakage. Polymerization shrinkage of the adhesive material may cause formation of microleakage-promoting microgaps between the adhesive material and the enamel surface, which may initiate white spot lesions under the bracket surface area.[6] In restorative dentistry, microleakage is defined as the seeping and leaking of fluids and bacteria between the tooth-restoration interface.[7] It is well documented that microleakage increases the likelihood of recurrent caries and postoperative sensitivity.[7] From the orthodontic point of view, it is possible to interpret this fact as the likelihood of formation of white spot lesions at and under the adhesive-enamel interface.

The null hypotheses tested in this study were: (1) the type of LCU used (QTH or LED) would not affect the amount of microleakage observed beneath brackets, and (2) the bracket type used (ceramic or metal) would not influence the amount of microleakage observed beneath brackets.

MATERIALS AND METHODS Return to TOC

Forty freshly-extracted noncarious premolars were collected and stored frozen (at 4°C) in deionized water until experiments took place (a maximum of 1 month). The enamel was checked under a transillumination unit (Pluraflex HL 150, Litema, GSD, Germany) for the absence of cracks and developmental defects. Teeth were cleaned off debris and further polished with pumice and rubber cups. Then, teeth were randomly assigned into four groups of 10 teeth each. The groups received the following bracket bonding procedures:

Group 1: A metal bracket (Ormco Series 2000, 1st and 2nd bicuspid w/hook, Optimesh XRT-based, 0.18-inch slot size, Ormco, Orange, Calif) was bonded to the tooth with Transbond XT (3M Unitek, Monriva, Calif) and cured with an LED curing unit (SmartLite, Dentsply/Caulk, Milford, Del) for 20 seconds (10 seconds each from mesial and distal margins). The materials and application procedures used for bracket bonding are presented in Table 1.

Group 2: A ceramic bracket (Mystique, NSB base with acrylic central base, 0.18-inch slot size, GAC, Bohemia, NY, USA) was bonded to the tooth with Transbond XT (3M Unitek, Monriva, Calif, USA) and cured with the same LED curing unit (SmartLite, Dentsply/ Caulk, Milford, Del, USA) as with group 1.

Group 3: A metal bracket (Ormco Series 2000, 1st and 2nd bicuspid w/hook, Ormco, Orange, Calif) was bonded with Transbond XT and cured with a QTH unit (Hilux, Benlioglu, Turkey) for 40 seconds (20 seconds each from mesial and distal margins).

Group 4: A ceramic bracket (Mystique, NSB base with acrylic central base, 0.18-inch slot size, GAC, Bohemia, NY) was bonded to the tooth with Transbond XT and cured with the same QTH curing unit (Hilux, Benlioglu, Turkey) as with group 3.

Specimens were stored in distilled water for 4 weeks at 37°C, after which thermal cycling in deionized water 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. Prior to dye penetration, the apices were sealed with sticky wax and the specimens were coated with two consecutive layers of nail varnish up to 1 mm from bracket margins. Specimens were then immersed in 0.5% basic fuchsin solution (Wako Pure Chemical Industry, Osaka, Japan) for 24 hours. After thorough rinsing with distilled water, the samples were air-dried and embedded in epoxy resin (Struers, Copenhagen, Denmark). In each sample, four parallel longitudinal sections were made through the labial surface (a total of 40 sections per group) using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, Ill) in the buccolingual direction.

All sections were examined by two calibrated investigators under a stereomicroscope (Wild Type 308700, Heerbrug, Switzerland) at standard magnification (16×) in a blinded fashion. Microleakage was determined by direct measurement using an Ultra-Cal IV digital caliper with an inherent accuracy of 0.02 mm (Ted Pella Inc, Redding, Calif).

Each section was scored for microleakage at the incisal and gingival levels along both interfaces (bracket-adhesive interface and adhesive-enamel interface). Scoring was made according to the following criteria (Figure 1):

Score 0: No dye penetration between the bracket-adhesive or adhesive-enamel interface.

Score 1: Dye penetration restricted to 1 mm into the bracket-adhesive or adhesive-enamel interface.

Score 2: Dye penetration into the inner half (2 mm) of the bracket-adhesive or adhesive-enamel interface.

Score 3: Dye penetration into 3 mm of the bracket-adhesive or adhesive-enamel interface.

In cases of disagreement between scoring, consensus was obtained by using the greater score. The schematic explanation of scoring is shown in Figure 1. Figures 2 and 3 demonstrate individual examples of scoring.

Statistical Analysis

For each adhesive interface investigated (bracket-adhesive or adhesive-tooth), the microleakage score was obtained by calculating mean incisal and gingival microleakage scores. For each specimen, the microleakage score was obtained by calculating the mean of incisal and gingival microleakage scores measured from four sections. Statistical evaluation of microleakage values between test groups was performed using Kruskal-Wallis tests and Mann-Whitney *U*-tests with Bonferroni correction (number of comparisons = 6). The level of significance was set at $P = .05$.

RESULTS Return to TOC

Microleakage was observed in all groups. Tables 2 and 3 demonstrate the microleakage scores of the adhesive-tooth and adhesive-bracket interfaces, respectively. Ceramic brackets cured with either LED or QTH LCUs (Groups 2 and 4) exhibited lower microleakage scores compared to those observed under metal brackets ($P < .05$). When the LED curing unit was used for photopolymerization, both adhesive interfaces under the ceramic brackets displayed significantly less microleakage than those under metal brackets. When the QTH curing unit was used, ceramic brackets displayed significantly less microleakage than did metal brackets in the bracket-adhesive interface along both gingival ($P = .001$) and incisal ($P = .002$) margins. However, although it was less than that found in metal brackets, the microleakage in the tooth-adhesive interface was not significantly different. The type of LCU (QTH or LED) did not result in a significant difference in the amount of microleakage observed beneath the bracket.

For metal brackets, the type of LCU did not significantly affect the amount of microleakage, except for gingival margins in the tooth-adhesive interface. When both bracket systems were compared, the use of LED under metal brackets resulted in the most dramatic difference in terms of microleakage. Overall, ceramic brackets cured with LED units yielded the best combination.

DISCUSSION Return to TOC

The potential of white spot lesion formation has become a particular clinical problem ever since direct-bonded orthodontic brackets were introduced.[8] Enamel demineralization and white spot lesions occur during and sometimes remain after orthodontic treatment.[9,10] It is reported that an average of two of the three teeth bonded with either of the bonding material were affected by some form of enamel opacity after orthodontic treatment, the most common type identified being a diffuse opacity.

O'Reilly and Featherstone[11] and Øgaard et al[12] have shown that visible white lesions can develop within 4 weeks. 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 as an underestimated threat to the permanent tooth, especially with regard to long-term fixed therapy. In the present study, adhesive-bracket and adhesive-tooth interfaces were scored separately. The adhesive-tooth interface is the critical one regarding the occurrence of white spot lesion, and the adhesive-bracket interface may have a role in bracket failure caused by bond degradation.

Effect of Bracket Type on Microleakage

As the number of adults seeking orthodontic treatment has increased, the need for more appealing brackets has led manufacturers to design esthetic ones, such as ceramic brackets. Studies with ceramic brackets have demonstrated their several undesirable effects, such as high incidence of bracket fracture, excessive wear, failure to deliver sufficient torque and enamel fractures during debonding,[13–15] yet these “transparent” brackets are more attractive and better received by patients than their metallic counterparts.

To date, many mechanical properties of ceramic brackets have been investigated, but no previous study appears to have tested microleakage beneath ceramic brackets. In the present study, the dye penetration method was chosen to assess microleakage. This is the most commonly used method to assess microleakage of adhesive materials.[16] According to the results of this in vitro study, microleakage tends to occur less under ceramic brackets than under metal ones, necessitating rejection of the second null hypothesis. Despite all the mechanical drawbacks of ceramic brackets, this finding might be of use in long-term clinical practice. Further studies should be conducted to clarify in vitro–in vivo correlation of microleakage under and around brackets.

In comparison with ceramic brackets, the metal brackets yielded worse microleakage resistance in this study. One explanation for this finding may be the "incomplete polymerization" phenomenon. In restorative dentistry, researchers have documented a number of factors that affect the depth of photoactivated cures, including duration and intensity of light exposure, filler type and shade of adhesive resin, and the reflective characteristics of adhesive resin bulk.[17–19] As the light passes through the bulk of the restorative resin material, its intensity decreases greatly, thus decreasing the potential for cure. This decrease results in a gradation of the cure such that it decreases from the top surface inwards.[20]

In orthodontics, brackets may act as the bulk of restorative material. Because metal brackets do not conduct light, it is highly possible that the underlying adhesive resin may remain incompletely polymerized. When testing shear-bond strength of brackets cured with LED units, Usumez et al[21] stated that the adherence of composite to the bracket was related to the cure of the resin. This may well explain the previous studies, which found higher bond strengths with ceramic brackets when compared to metal ones.[15,22,23] However, the lower microleakage scores obtained herein need to be tested mechanically before any correlation is established between microleakage and bond strength.

Effect of LCU Type on Microleakage

Decreasing total cure time for adhesive and composite material is apparently beneficial for both clinician and patient. LED units are being marketed aggressively because they offer ultimate polymerization with shorter periods of light exposure. Studies have shown that powerful LED units have the potential to replace conventional QTH units.[2,24,25] Previous research on the dental application of LED units compared with QTH units have demonstrated that LED units perform as well as or better than QTH units at the same level of irradiance.[2,21] Especially when used in the soft-start mode, LED curing units have been shown to reduce polymerization shrinkage and microleakage[26] and produce higher bracket bond strength than that obtained with conventional QTH units.[27] In the present study, the first null hypothesis was accepted in part because, with the exception of the gingival margins at the tooth-adhesive interface of metal brackets, the type of LCU did not significantly affect the amount of microleakage.

A recent study by Dunn and Taloumis[28] demonstrated that two different commercial LED units providing a power density of 150 mW/cm^2 bonded brackets to etched tooth enamel as well as QTH units. The emitted light spectrum of LED units differs from that of QTH units, and therefore the photoinitiator systems of some composites need to be adjusted to the spectrum of this new light source.[29,30] Therefore, if LED units are preferred for polymerization instead of halogen LCUs, the adhesive resin material should be carefully selected.[29,31]

In the present study, Transbond XT was used. The compatibility of this adhesive with various LED units, as well as with plasma arc and argon laser curing units, has been well documented.[6,16,21] Thus, the present study confirms previous ones in that the LED curing unit reduced the total amount of time needed for bracket bonding without compromising polymerization of the adhesive. However, the questions regarding the optimal cure times for LED units and their ability to cure resins universally still merit further research.[21,32]

CONCLUSIONS Return to TOC

- Microleakage was observed along all bonding interfaces, regardless of the type of bracket or LCU used. More effort should definitely be made regarding prevention of enamel demineralization during long-term orthodontic treatment.
- The tested LED curing unit may provide a reduction in chair time but may cause more leakage between adhesive-bracket interface when metal brackets are used.
- Regardless of the type of curing unit used, ceramic brackets exhibited lower microleakage scores than metal brackets.
- Bonding of ceramic brackets with an LED-compatible adhesive resin and photopolymerized with a LED curing unit may significantly reduce the amount of microleakage that will occur beneath the bracket.

ACKNOWLEDGMENTS

The authors would like to express special thanks to Dr. Murat Demirhanoglu for kindly donating the ceramic brackets used in the present study.

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TABLES Return to TOC

TABLE 1. Materials and Application Procedures

Material	Component	Chemical Composition	Steps of Application
Unitek Etching Gel	Acid	35% orthophosphoric acid	Apply and leave for 15 s, rinse thoroughly, air dry
Transbond XT Primer	Primer	Bisphenol A diglycidyl ether dimethacrylate, triethylene glycol dimethacrylate	Apply a thin coat on enamel
Transbond XT Light Cure Adhesive	Paste	Quartz silica bisphenol A diglycidyl ether dimethacrylate, bisphenol A bis (2-hydroxyethyl ether) dimethacrylate	LED light source: light cure for 10 s QTH light source: light cure for 20 s

TABLE 2. Comparison of Microleakage Scores between Adhesive-Tooth Interfaces[a]

Groups	Variables ($\bar{x} \pm SD$) Incisal	Gingival	Overall
Group 1	1.52 ± 0.569 A[b]	2.17 ± 0.468 B,C	1.85 ± 0.425 D
Group 2	0.81 ± 0.251 A	0.99 ± 0.341 B	0.90 ± 0.233 D
Group 3	1.30 ± 0.576	1.30 ± 0.616 C	1.30 ± 0.569
Group 4	1.00 ± 0.636	1.01 ± 0.526	1.01 ± 0.555
	$\chi^2 = 9.132$ $P < .05$	$\chi^2 = 18.153$ $P < .05$	$\chi^2 = 14.580$ $P < .05$

[a] Significance was determined at a probability value of $P < .05$. Note that groups 1–4 and 2–3 are not comparable with two independent variables. $\bar{x}$ indicates mean; SD, standard deviation.
[b] Values followed by same letters indicate microleakage scores that are significantly different at $P < .05$.

TABLE 3. Comparison of Microleakage Scores between Adhesive-Bracket Interfaces[a]

Groups	Variables Incisal $\bar{x} \pm SD$	Gingival $\bar{x} \pm SD$	Overall $\bar{x} \pm SD$
Group 1	2.63 ± 0.505 A[b]	2.83 ± 0.172 C	2.73 ± 0.323 E
Group 2	0.82 ± 0.407 A	0.65 ± 0.438 C	0.74 ± 0.376 E
Group 3	2.31 ± 0.880 B	2.19 ± 0.823 D	2.25 ± 0.821 F
Group 4	0.69 ± 0.656 B	0.55 ± 0.716 D	0.62 ± 0.671 F
	$\chi^2 = 24.640$ $P < .05$	$\chi^2 = 26.924$ $P < .05$	$\chi^2 = 25.768$ $P < .05$

[a] Significance was determined at a probability value of $P < .05$. Note that groups 1–4 and 2–3 are not comparable with two independent variables. $\bar{x}$ indicates mean; SD, standard deviation.
[b] Values followed by same letters indicate microleakage scores that are significantly different at $P < .05$.

FIGURES Return to TOC

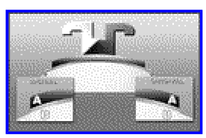

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Figure 1. Schematic explanation for the scoring method used. A indicates adhesive bracket interface; B, adhesive-tooth interface

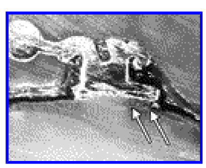

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Figure 2. A specimen with metal bracket, demonstrating microleakage. For the adhesive-tooth interface, scores are 0 for gingival and 2 for incisal. For the adhesive-bracket interface, scores are 0 for gingival and 2 for incisal

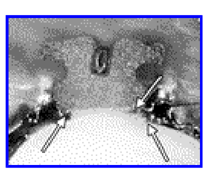

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Figure 3. A specimen demonstrating microleakage beneath ceramic bracket. For the adhesive-tooth interface, scores are 2 for gingival and 0 for incisal. For the adhesive-bracket interface, scores are 2 for gingival and 1 for incisal

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