Effect of high-power LED light curing unit on bond strength of composite resin to dentin

Tomomasa Nomura, DMD,[a] Ichiro Ikeda, DMD, PhD,[a] Masayuki Otsuki, DDS, PhD,[a] and Junji Tagami, DDS, PhD[a,b]

[a]Cariology and Operative Dentistry, Department of Restorative Sciences, Graduate School of Medical and Dental Sciences, and [b]Global Center of Excellence Program, International Research Center for Molecular Science in Tooth and Bone Diseases, Tokyo Medical and Dental University, Tokyo, Japan

Purpose: This study evaluated the effect of a high-power solid-state light emitting diode (LED) curing unit on the dentin bond strength of a composite resin with self-etching primer adhesives by means of microtensile bond test.
Materials and Methods: The flat dentin surfaces of the extracted human molars were prepared. Each surface was treated with either two self-etching adhesive systems (Clearfil SE Bond, Clearfil Tri-S Bond) and a photocure composite was placed. The adhesive and composite were photocured with a high-power LED, a conventional LED, or a halogen light curing unit. In high-power LED group, the exposure time was reduced 3 or 5 s for the adhesive and 5 or 10 s for the composite. The specimens were trimmed to obtain the stick shape specimens and the micro-tensile bond strengths were measured. The spectrum of the wavelength of each light curing unit was also measured.
Results: In Clearfil SE Bond group, the microtensile bond strengths of high-power LED light curing unit groups were statistically lower than that of a halogen light curing unit group. In Clearfil Tri-S Bond group, there were no statistical differences in the microtensile bond strengths between halogen and high-power LED light curing unit groups, when the composite was photocured for 10 s. The spectrum of both high-power and conventional LED light curing units had a single sharp peak around 465 nm. The conventional halogen light curing unit showed broad spectra.
Conclusion: A high-power LED curing unit affected the dentin bond strength of a composite resin with self-etching primer adhesives. **(Int Chin J Dent 2010; 10: 35-40.)**
Key Words: composite resin, LED light curing unit, microtensile bond test

Introduction

The photo-curable adhesive and composite resin are widely used for the tooth restorative treatment. This technology had been based on the combination with camphorquinone (CQ) as a photo-initiator and the quartz tungsten halogen (QTH) light with a bandpass filter as a light source for the polymerization.

Since the solid-state light emitting diode (LED) technology was introduced for polymerizing dental materials,[1] there have been many researches for the LED light curing units (LCUs) concerning various properties[2-17] including the bond strength.[1,18-20] The output power of the LED LCU has been increased expecting the reduction of the exposure time for both adhesive and composite resin. The highest light intensity of the LED LCU is comparable to the plasma arc LCU. In a busy practice, the exposure duration can have an impact on the total time of a treatment procedure.[17]

However, it is unknown how long the high-power LED LCU can reduce the exposure time. The purpose of this study was to evaluate the effect of a high-intensity LED LCU on the dentin bond strength of a composite resin with self-etching primer adhesives by means of microtensile bond test.

Materials and Methods

Specimen preparation

Forty-two caries-free extracted human molars were used for this study. This research design was subjected to the guideline of the ethical committee, Faculty of Dentistry, Tokyo Medical and Dental University. After cleaning with a scalar, the roots were removed. Occlusal surfaces of the teeth were ground using a model trimmer to obtain flat mid-coronal dentin surfaces perpendicular to the long axis of the tooth, and then polished with a 600 grit silicon carbide paper (Sankyorikagaku, Saitama, Japan). A black plastic ring of 8 mm in diameter and 2 mm in height was placed on the center of the prepared dentin surfaces and fixed using a wax.

The resinous materials and LCUs used in this study were listed in Table 1 and 2 respectively. A two-step self-etch adhesive (Clearfil SE Bond, SE, Kuraray Medical, Tokyo, Japan), a one-step self-etching adhesive (Clearfil Tri-S Bond, TS, Kuraray Medical) and a universal photo-curable composite resin (Clearfil AP-X, Kuraray Medical) were employed for this study. A QTH LCU (CoBee, GC, Tokyo, Japan), a conventional LED LCU (G-light, GC) and a high-power LED LCU (Mini LED III, Satelec, Boudreaux, France) were used for curing the adhesives and the composite resin. The original G-light contained one violet and seven blue LEDs as light source. It was modified disconnecting a violet LED and only blue LED was used in this study.

Table 1. Materials used in this study.

Materials, Code	Ingredients
Clearfil SE Bond, SE	
Primer	MDP, HEMA, Hydrophilic dimethacrylate, *dl*-Camphorquinone, *N,N*-Diethanol-*p*-toluidine, Water
Bond	MDP, Bis-GMA, HEMA, Hydrophobic dimethacrylate, *dl*-Camphorquinone, *N,N*-Diethanol-*p*-toluidine, Silanated colloidal silica
Clearfil TriS Bond, TS	MDP, Bis-GMA, HEMA, Hydrophobic dimethacrylate, *dl*-Camphorquinone, Ethyl alcohol, Water, Silanated colloidal silica
Clearfil AP-X (A3 Shade)	Silanated barium glass, Silanated colloidal silica, Silanated silica, Bis-GMA, TEGDMA, *dl*-Camphorquinone

Manufacturer, Kuraray Medical; MDP, 10-Methacryloyloxydecyl dihydrogen phosphate; HEMA, 2-Hydroxyethyl methacrylate; Bis-GMA, Bisphenol A-glycidyl methacrylate; TEGDMA, Triethyleneglycol dimethacrylate

Table 2. Light curing units used in this study.

Light curing units, Code (Manufacturer)	Light sources	Light intensity
Co-Bee, CB (GC)	Halogen	770 mW/cm^2
G-Light*, GL (GC)	Blue LED	650 mW/cm^2
Mini LED III, ML (Satelec)	Blue LED	1,900 mW/cm^2

*Modified from an original model

The dentin surface in the plastic ring was treated with either SE or TS and irradiated with each LCU. Then Clearfil AP-X was injected into the ring as a bulk and photocured with same LCU as irradiation to the adhesive. Experimental groups, the irradiation time and energy in each group were shown in Table 3. The total energy provided is calculated by multiplying the power density of the light by its exposure duration.

Microtensile bond test

After storage in water at 37ºC for 24 hours, each specimen was vertically crosscut and re-crosscut to approximately 0.7 mm x 0.7 mm using a low speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) under water cooling to obtain the stick shape specimens. The final width and thickness of the bonded areas were measured using a digital caliper (Mitsutoyo, Kawasaki, Japan). The specimen were attached to a testing device (Bencor-Multi-T, Danville Engineering, San Ramon, CA, USA) with a cyanoacrylate adhesive (Model Repair II Blue, Dentsply-Sankin, Otawara, Japan) and subjected to the microtensile bond test at a crosshead speed of 1 mm/minute using a table-top material tester (EZ-Test, Shimadzu, Kyoto, Japan). The number of the experimental specimen was 30 in each group (n=30). After the microtensile bond strengths (μTBS) were measured, all of the specimens were inspected visually and microscopically (x20, Dentcraft Dent-Optics DX, Yoshida, Tokyo, Japan) to determine the modes of failure.

Spectrum of wavelength of LCU

The spectrum of the wavelengths of each LCU was measured using a spectroradiometer (USR-40, Ushio, Tokyo, Japan).

Statistical analysis

The µTBS data were analyzed by using a two-way and a one-way ANOVA followed by Tukey's honestly significant difference test at the 95% level of confidence.

Table 3. Experimental groups.

Experimental groups	Adhesives	LCU	Irradiation time (s)		Irradiation energy (mJ)	
			Adhesive	Composite	Adhesive	Composite
SE-CB-10-40	SE	CB	10	40	32.5	154.0
SE-GL-05-10	SE	GL	5	10	16.3	32.5
SE-GL-10-40	SE	GL	10	40	32.5	130.0
SE-ML-03-05	SE	ML	3	5	28.5	47.5
SE-ML-05-05	SE	ML	5	5	47.5	47.5
SE-ML-03-10	SE	ML	3	10	28.5	95.0
SE-ML-05-10	SE	ML	5	10	47.5	95.0
TS-CB-10-40	TS	CB	10	40	32.5	154.0
TS-GL-05-10	TS	GL	5	10	16.3	32.5
TS-GL-10-40	TS	GL	10	40	32.5	130.0
TS-ML-03-05	TS	ML	3	5	28.5	47.5
TS-ML-05-05	TS	ML	5	5	47.5	47.5
TS-ML-03-10	TS	ML	3	10	28.5	95.0
TS-ML-05-10	TS	ML	5	10	47.5	95.0

Results

The µTBS of each group was shown in Table 4 and the failure mode was summarized in Fig. 1. For SE groups, µTBSs of ML groups were statistically lower than that of SE-CB-10-40 and SE-ML-05-10 showed no difference comparing with that of SE-GL-10-40. There were no differences among SE-ML groups. For TS groups, µTBS of TS-ML-03-05 and TS-ML-05-05 were statistically lower that of TS-CB-10-40. The µTBS of TS-ML-03-10 and TS-ML-05-10 showed no differences comparing with that of TS-CB-10-40. The µTBS of TS-ML-05-10 was statistically higher than those of TS-ML-03-05 and TS-ML-05-05. There were no interaction between the adhesive systems and the irradiation condition on the µTBS. There was not specific tendency in the failure mode.

Table 4. Microtensile bond strength (µTBS).

Experimental groups	µTBS (SD)	Experimental groups	µTBS (SD)
SE-CB-10-40	84.8 (11.4) a	TS-CB-10-40	63.2 (10.4) d, e
SE-GL-05-10	42.6 (14.6)	TS-GL-05-10	59.2 (13.6) d, e
SE-GL-10-40	77.4 (10.9) a, b	TS-GL-10-40	62.0 (9.8) d, f
SE-ML-03-05	61.2 (9.6) c	TS-ML-03-05	31.5 (9.4) g
SE-ML-05-05	59.2 (7.5) c	TS-ML-05-05	44.9 (7.5) g, h
SE-ML-03-10	63.4 (9.1) c	TS-ML-03-10	52.0 (9.2) e, h
SE-ML-05-10	69.3 (14.9) b, c	TS-ML-05-10	57.8 (8.5) e, f

Identical letters showed no statistical differences ($p<0.05$).

The spectrum of the wavelengths of each LCU was shown in Fig. 2. CB had relatively broad spectra (390-530 nm) with peak wavelength of 490nm. GL showed sharp peak wavelength of 467 nm and ML showed higher sharp peak wavelength of 463 nm.

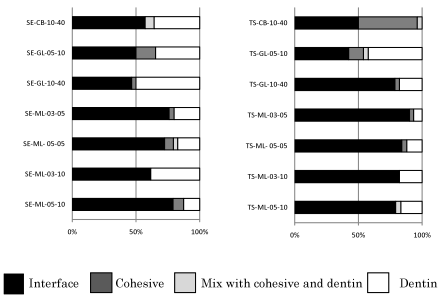

Fig. 1. Mode of failure

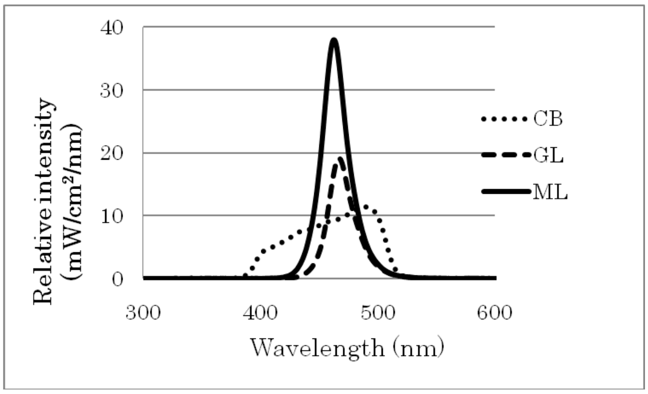

Fig. 2. Spectrum of wavelength of LCUs

Discussion

Since "first generation LED LCU"[9] was marketed, the intensity has been dramatically increased expecting the reduction of the exposure time to polymerize the resin materials. However, under higher irradiance, the shorter lifetime of free radicals would cause insufficient polymerization.[20] This study showed that the microtensile bond strengths of self-etching primer adhesives to the dentin were affected by the exposure time of the high-power LED LCU.

In this study, the microtensile bond test using the stick shaped specimens was employed. The microtensile bond test was widely used and was established as the evaluation of adhesive property.[18,19,21,22] The different specimen designs, such as stick, dumbbell or hourglass shape, had no influence on the bond strength to dentin.[21] The stick shape specimen seemed to be the favorable design, as it is easy preparation, and is not subject to the effects of specimen geometry.[21]

Although, all ML groups showed less μTBS than CB group among SE groups, ML-03-10 and ML-05-10 showed no significant differences compared with CB group among TS groups. It was reported that the bond strengths of resin composites cured with LED LCUs were significantly lower than values produced with a QTH LCU.[8] The dentin bond strength of SE cured with the LED LCU had a lower value than that cured with the QTH LCU.[10] The other hand, there were no statistically significant differences between bond strengths of SE to enamel with QTH or with LED LCU.[18] The microhardness of SE was also affected by light source.[5] There are many factors of the LCU affected bond strength; wavelength spectra, output power, exposure time for adhesive and composite, distance between light tip and irradiated surface, focus of light, temperature, exposure methods. One possible explanation might involve the narrow emission spectrum of the LED LCU.[10]

The high intensity LCU is expected to penetrate through composite resin and to contribute the polymerization of the underlying adhesives. It was reported that the second photoirradiation to the adhesive through the resin composite might increase dentin bond strength.[23] However, another research suggested that the required light of shorter wavelength could not penetrate through the overlying composite and that the bonding system should be polymerized before it was covered by the resin composite.[24] Many factors affect light penetration through a composite.[17] Although the emission spectra of LCUs varies greatly, as does the power delivered at different wavelengths,[17] it was suggested that the adhesive and restorative materials themselves might be a more critical factor in adhesion than the light source or curing method.[1,19]

Some dental resins and bonding systems employ other photoinitiators that are not as chromogenic as CQ. These alternative photoinitiators are more sensitive to the shorter wavelengths (<420 nm) of blue light.[24] Two adhesives used in this study contain not only CQ as a photoinitiator, but also another one (personal communication with the manufacturer) which reacts with low wavelength of visual light as well as phenylpropanedione (PPD). Generally the manufacturers of the adhesive materials have not disclosed their photocatalyst systems in detail. The manufacturers should inform the absorption profile of the dental resins in the product data sheet, as well as the spectral band emitted by the LCU.[7] Although the LED is not inferior to the halogen light for CQ activation, its narrow emission spectrum has a theoretical weakness for activating co-initiator with a different absorption spectrum from CQ.[10,24] Curing of materials containing co-initiators should be more challenging for LED LCUs.[4]

The light exposure time and intensity affect not only bond strength but also various mechanical properties of the adhesives and composite resins. The low intensity LED LCU required the extension of the exposure duration for achieving the adequate mechanical property of the composite resin.[2-4,6,17] The high-power LED LCU produced an acceptable level of polymerization of composites as well as QTH LCU.[14,15] The effect of light sources on microhardness was material-dependent[12] and the different composites required different exposure times.[16]

The LED LCU might reduce the risk of pulp injury, because of the lesser temperature rise compared to halogen units.[11] However, higher power LED LCU would produce more heat. The intensity of LCU, the curing time and the enthalpy of polymerization of the resin composite were the most important factors in causing potentially dangerous temperature increases in the pulp. The composite is a good insulator and the greatest risk occurs when using the light to cure the thin layer of bonding resin or in deep restorations.[25] Such high temperatures are detrimental to the dental pulp.[13]

If μTBS of TS-CB-10-40 is clinically acceptable, those of TS-ML-03-10, TS-ML-05-10 and all SE-ML groups might be acceptable and the exposure time could be reduced using high power LED LCU, because there were no significant differences among them. In this study, it was concluded that the high-power LED LCU affected the dentin bond strength of a composite resin with self-etching primer adhesives. Manufacturer-recommended exposure duration values are not reliable indicators of optimal composite performance.[17] Care must be taken when interpreting the conclusions of any study that demonstrates the superior performance of LCU, because the results are only valid for the particular resin composite and shade used in the study.[24]

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Correspondence to:

Dr. Tomomasa Nomura
Cariology and Operative Dentistry, Department of Restorative Sciences,
Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University,
1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8549, Japan.
Fax: +81-3-5803-0195 E-mail: t-nom501@wj9.so-net.ne.jp

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