Light-Emitting Diode Technology for Orthodontic Bonding

VITTORIO CACCIAFESTA, DDS, MSC
MARIA FRANCESCA SFONDRINI, MD, DDS
PAUL-GEORG JOST-BRINKMANN, DMD, PHD
ANDREAS BOEHME, DDS

Although halogen light-curing units are the most common type used to cure orthodontic adhesives, this technology has several drawbacks. Halogen bulbs have a limited effective lifetime of approximately 40-100 hours.[1] In addition, high temperatures cause a gradual degradation of the halogen bulb, reflector, and filter, reducing the intensity of the light output and thus the unit's effectiveness in curing composite resins.[2] The clinical implication is that with an aging light-curing unit, adhesives will be less well cured, with poorer physical properties and an increased risk of bond failure.

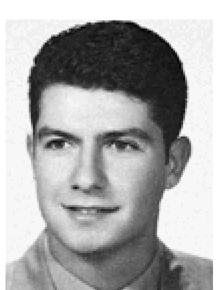
In addition, several studies have demonstrated that many dental halogen light-curing units do not reach the minimum power output specified by the manufacturers.[2-4] This can be a result of improper maintenance, including failure to make a critical check of the light irradiance and to replace the filter and the halogen bulb on a regular basis.

Recently, high-intensity light-curing units such as xenon-arc sources have been introduced in clinical practice, with the advantage of reduced curing times. These devices, however, are more complex and more costly compared with halogen sources.

As another alternative to halogen light-curing units, light-emitting diode (LED) technology has recently been proposed for curing dental composites.[5] LEDs are semiconducting materials that transform current into light of a specific wavelength. They are much smaller and lighter than conventional bulbs. They offer high shock resistance, as there is no filament to be damaged, and their relatively low power consumption makes them suitable for portable use in cordless devices. LEDs have lifetimes of more than 10,000 hours and experience little degradation of light output over this time—a distinct advantage over halogen bulbs.[6] In addition, LEDs require no filters to produce blue light. The spectral output of these LEDs falls mainly within the absorption spectrum of the camphoroquinone photoinitiator (400-500nm) of most dental composites.

LED sources have been found to produce a depth of cure significantly greater than that achieved with a conventional halogen light.[7,8] No significant differences in compressive strength,[9] flexural strength, or modulus[10] were found between composites polymerized with halogen units and those cured with LED units. To date, however, the curing efficacy of LEDs in bonding orthodontic brackets has not been fully investigated. The purpose of this article is to describe a new LED curing source and to compare the effects of halogen and LED curing units on the shear bond strength of a composite resin used for

Drs. Cacciafesta and Sfondrini are Assistant Clinical Professors, Department of Orthodontics, University of Pavia, Italy. Contact Dr. Cacciafesta at Piazza Dante 3, 27100 Pavia, Italy; e-mail: vcacciafesta@hotmail.com. Dr. Jost-Brinkmann is an Associate Professor and Dr. Boehme is a postgraduate resident, Department of Orthodontics and Dentofacial Orthopedics, Humboldt University of Berlin, University Hospital Charité, Berlin, Germany.


Dr. Cacciafesta


Dr. Sfondrini


Dr. Jost-Brinkmann


Dr. Boehme

direct bonding of stainless steel brackets.

GC E-Light

The GC E-Light* contains an array of 64 F-grade LEDs that produce an intensity as high as 1,500mW/cm² (calculated by dividing the power of the unit by the area of the light guide). The unit is manufactured as a cordless handpiece, incorporating the diode array, the battery holder,

Fig. 1 GC E-Light.

Fig. 2 LCD screen, keyboard, and memory compartment.

Fig. 3 Scanning bar codes supplied by manufacturers of orthodontic adhesives.

and a compartment housing the interchangeable memory module and a socket for Internet connection (Fig. 1).

Just above this compartment are the keyboard for menu selection and the LCD display (Fig. 2). The top line of the LCD screen displays the menus and selected programs, while the bottom line shows a battery-charge indicator, an indicator for Internet connection, and a countdown timer. The keyboard has four buttons: the two navigation buttons are used to switch from one menu to another and to select programs, the validation button to confirm the selected menu, and the return button to go back to the main menu.

The E-Light offers a wide variety of menus and curing programs (Table 1). With the "Favorites" menu, it is possible to consult the 15 previously used curing modes or adhesives. The fast-curing menu has three different modes (six, nine, and 12 seconds), each with the unit at an intensity of about 1,500 mW/cm^2. The pulse-curing menu produces full power in a pulsating mode—in other words, an emission of flashes at different intervals, with a relaxation period of 250 milliseconds between light exposures. The intensity of the unit in this mode is also around 1,500mW/cm^2. The traditional curing menu contains five different programs, simulating a halogen unit:

1. Medium (40 seconds at 450mW/cm^2)
2. Standard (40 seconds at 750mW/cm^2)
3. Turbo (10 seconds at 1,200mW/cm^2)
4. Soft-start curing A (20 seconds from 0-1,200mW/cm^2 and 20 seconds at 1,200mW/cm^2)
5. Soft-start curing B (20 seconds from 0-600mW/cm^2 and 20 seconds at 600mW/cm^2)

The library menu contains the names of visible-light-cured materials that have been stored in the memory of the unit. If the desired adhesive is not listed, the list can be updated by changing the memory module, downloading the information from the Internet, or using the handpiece to scan a bar code supplied by the manufacturer (Fig. 3). The download menu is used to upgrade the system software, the curing profiles, and the materials library by connecting a serial cable between the unit and the nine-point serial port of a computer. The bar-code menu automatically programs the unit in the appropriate polymerization mode.

The lithium-ion battery provides sufficient power for 300 light-ups of three seconds each on full power or 15 minutes each in soft-start curing mode.

TABLE 1
MENUS AND CURING PROGRAMS OF THE GC E-LIGHT

Menu	Curing Programs
Fast cure	6 seconds
	9 seconds
	12 seconds
Pulse cure	6 x 1 second
	10 x 1 second
	10 x 2 seconds
Traditional	Medium (40 seconds)
	Standard (40 seconds)
	Turbo (10 seconds)
	Soft cure A (40 seconds)
	Soft cure B (40 seconds)
Download	
Bar code	
Favorites	
Library	

Experimental Investigation

We performed an in vitro study to evaluate the shear bond strengths of a composite resin (Transbond XT**) cured with two different light sources: a halogen unit (Astralis 10***) and an LED unit (GC E-Light).

Thirty freshly extracted bovine permanent mandibular incisors were randomly divided into two groups of 15 specimens each. The teeth were

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cleansed of soft tissue and then embedded in cold-curing, fast-setting acrylic, with each tooth oriented so that its labial surface would be parallel to the force during the shear bond test. Before bonding, the facial surface of each incisor was cleaned with a mixture of water and fluoride-free pumice, using a rubber polishing cup for 10 seconds. The enamel surface was then thoroughly rinsed with water and dried with an oil-free air stream.

Maxillary central incisor brackets with .018" slots (Victory Series**) were bonded to each tooth by the same operator, using a conventional orthodontic light-cured adhesive (Transbond XT**) according to the manufacturer's directions. Each enamel surface was etched with 37% phosphoric acid gel for 30 seconds, followed by thorough rinsing and drying. After application of the primer, the bracket was bonded near the center of the facial surface of the tooth with sufficient pressure to express excess adhesive, which was removed with a scaler before polymerization.

The halogen light-curing unit was set to the high-power program (HIP, light intensity: 1,200mW/cm^2), and the LED source to the fast-curing mode (light intensity: 1,500mW/cm^2). Although the Transbond XT manufacturer's recommended curing time for metal brackets with a conventional halogen light is 20 seconds, the high intensity of the Astralis 10 allows curing time to be reduced to 10 seconds. Therefore, the curing protocols were as follows:

Group A: Cured with the halogen light for 10 seconds (five seconds each from the mesial and the distal).

Group B: Cured with the LED light for six seconds (three seconds each from the mesial and the distal).

With each source, the light tip was inclined at a 45° angle to the buccal enamel and placed as close as possible to the bracket base.

After bonding, the samples were stored for 24 hours in distilled water at room temperature. Shear testing was then conducted with an Erichsen-Wuppertal Testing Machine.† The speci-

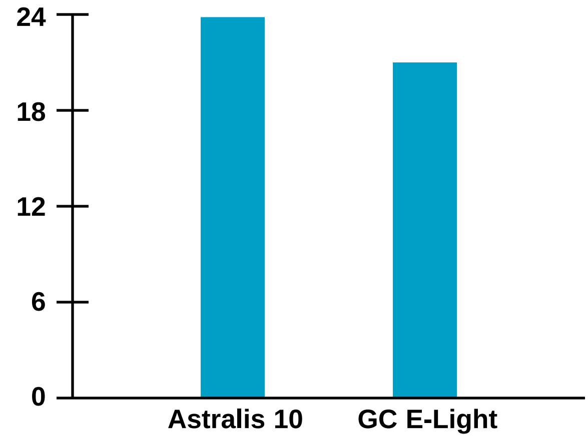

Fig. 4 Shear bond strengths (MPa) of two groups tested.

TABLE 2
SHEAR BOND STRENGTHS (MPA)

	No.	Mean ± S.D.	Median	Range
Astralis 10	15	23.7 ± 7.3	26.2	9.1-34.2
GC E-Light	15	19.9 ± 5.7	20.3	10.0-28.0

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†AMETEK Precision Instruments, Meerbusch, Germany.

mens were stressed in an occlusogingival direction at a crosshead speed of 1mm/minute. The maximum load necessary to debond or initiate bracket fracture was recorded in Newtons and converted to megapascals (MPa) as a ratio of Newtons to the surface area of the bracket.

According to Student's t-test, no statistically significant difference ($p = .12$) was found between the mean shear bond strength of the group cured with the halogen light and that of the group cured with the LED source (Fig. 4, Table 2).

Discussion

As this study demonstrates, the GC E-Light can cure orthodontic brackets more rapidly (six seconds) than the Astralis 10 light (10 seconds), with no significant reduction in bond strength. Both devices produced shear bond strengths above the clinically acceptable limits suggested by Reynolds.[11] Therefore, LEDs can be recommended as a viable alternative for curing composite resins in orthodontic bonding.

LEDs offer a number of advantages over conventional halogen light-curing units. The rise in temperature during polymerization of composite resins with a halogen light is twice that with an LED unit.[12] In addition, because no wavelengths outside the 450-490nm range are emitted by LEDs, there is no need for filters, and the energy input-to-output efficiency is higher. This has allowed manufacturers to produce portable, cordless units with rechargeable batteries.

Further clinical investigations comparing the failure rate of direct-bonded brackets cured with the GC E-Light to that of brackets cured with conventional halogen units are currently in progress.

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