ORIGINAL ARTICLE

Effective single-charge end point of cordless light-emitting diode light-curing units

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Introduction: The purpose of this study was to evaluate the battery lives of cordless light-emitting diodes (LEDs) and their effect on orthodontic bracket bond strength. **Methods:** One hundred eighty-six metal orthodontic brackets were bonded to extracted molars. Two LED light-curing units (L. E. Demetron [SDS/Kerr, Orange, Calif] and Ortholux [3M Unitek, Monrovia, Calif]) were evaluated. Each light was used to bond 93 specimens. One bracket was bonded every 5 minutes until the battery ran out. The lights were activated for 20 seconds, then automatically turned off for 40 seconds every minute (33% duty cycle) without recharging. Bonded specimens were stored in water at 37°C for 24 hours and then subjected to shear force with a universal testing machine until bracket failure. **Results:** Repeated measures ANOVA detected significantly weaker mean shear bond strength and fewer consecutive cures with the Ortholux compared with the L. E. Demetron light-curing unit. However, when the first 5 time points were excluded, there were no differences between the 2 lights, demonstrating that the lights performed similarly after the first 20 minutes of operation Just before battery failure, both lights still provided the same power density as at the beginning. **Conclusions:** Both light-curing units provided adequate power density for up to 2 hours without recharging at a 33% duty cycle. There was no significant decrease in power in cordless LED light-curing units as the battery life approached its end point. (Am J Orthod Dentofacial Orthop 2006;130:378-84)

Visible light-curing units (LCUs) play an important role in the practice of modern clinical orthodontics by providing rapid resin-based composite polymerization on command. Resin polymerization occurs when carbon double bonds in methacrylate monomers are selectively converted into single bonds, propagating polymer growth, by free radicals created by the activation of diketone photoinitiators by light in the blue range of the visible spectrum at approximately 468 nanometers (nm).[1] Currently, most sources of visible blue light used in orthodontic practice are quartz-tungsten-halogen (QTH) LCUs. Despite their popularity, QTH lights have several drawbacks. Conventional units operate by heating a tungsten filament, similar to an incandescent light bulb, to generate light; they also generate a significant amount of heat, and the process in inherently inefficient because only 1% of the initial energy input is actually converted into blue light for composite polymerization.[2] The heat generated from QTH light systems can cause blistering of sensitive light filters and discoloration of the reflectors, and the cooling fan can be noisy and disperse any bacterial aerosol in the patient's mouth.[3] In addition, halogen bulbs last approximately 50 hours[4] and should be replaced every 6 months.[5] Studies have shown that private dental offices do not routinely service their QTH LCUs, and many LCUs have an output that is inadequate for polymerization.[6,7] Other methods for curing dental composite resins use xenon plasma arc lights and argon lasers. Although these lights dramatically reduce the curing time for dental composite resins, they are substantially more expensive and bulky.

In 1995, after improvements in blue light-emitting diode (LED) semiconductor technology, LEDs were proposed as a light source for the polymerization of light-cured resins.[8,9] LEDs are solid-state light sources that convert electrical energy directly into light.[10] Because they are solid-state devices, they can be manufactured to extremely small dimensions and withstand mechanical shock and vibration with low failure rates. LEDs are in everyday household appliances such as indicator lights and sensors, and in the dashboard instrument panels of automobiles, and they can have a lifetime of up to 10,000 hours.[11] LEDs are manufactured by metal-organic chemical vapor deposition of different semiconductor materials in films that are

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layered on top each other. The most recent blue LEDs use indium-gallium-nitride technology to generate high-energy photons in the blue region of the visible light spectrum.[12] As electrical current flows through the semiconductor chip in an LED, electrical energy is converted directly into light with little energy lost as heat. The result is a stable, efficient, long-lasting output of blue light in the range of 440 to 480 nm with no need for a cooling fan.[3] The narrow spectral emission band of LEDs closely overlaps the spectral absorption peak of the common dental photoinitiator, camphoroquinone, at 468 nm; this means that the LED is very efficient at polymerization.[8] The efficient energy conversion of LEDs has allowed the development of cordless LCU units that operate silently and have a long bulb life.[10]

Composite resins cured with LEDs appear to have physical properties equivalent to resins cured with QTH units.[12-14] Initial studies demonstrated that increased curing time or decreased composite resin material thickness was necessary to obtain equivalent mechanical properties in the composite with the first generation of LED LCUs.[15,16] Although depth of cure is an important consideration for the restorative dentist, it is much less of a concern for the orthodontist because the layer of composite that bonds brackets to tooth structure is significantly thinner. The first generation LED LCUs could cure a 0.7-mm-thick increment of composite in 40 seconds.[15] Although this rate of cure might be unfavorable for restorative dentistry,[17] LEDs can provide an efficient method for bonding orthodontic brackets to tooth enamel. It has been reported that bond strengths from 3 to 7.85 MPa might be adequate to withstand orthodontic forces.[18,19] Recent studies demonstrated acceptable shear bond strengths of brackets bonded with commercially available LEDs[20,21]; however, no studies have evaluated the shear bond strength of orthodontic brackets to teeth with cordless LEDs when teeth are consecutively polymerized without recharging. Orthodontists often bond an entire arch, up to 10 brackets, with no pause between teeth. With the manufacturer's usual recommendation of a 20-second curing time per bracket, this could mean that an LCU would operate for at least 200 seconds. It is also possible that, if a multiple-chair office shares an LCU, the light might have to perform many bonding procedures on several patients before recharging. The purpose of this study was to evaluate the ability of commercially available LEDs to consecutively bond orthodontic brackets to teeth on a single charge.

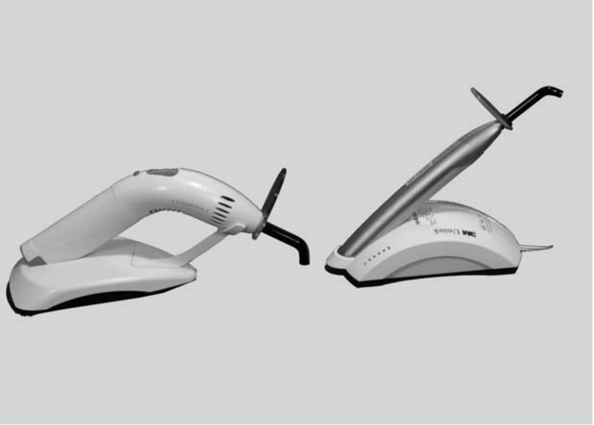

Fig 1. LED LCUs used in study: *left,* L. E. Demetron; *right,* Ortholux.

MATERIAL AND METHODS

One hundred eighty-six extracted human molars were collected and stored in 0.5% chloramine-t solution for no longer than 6 months before the start of the study. Teeth with caries, cracks, hypocalcification, peculiar morphology, or other visible defects were excluded. The roots of the teeth were notched and embedded in laboratory stone (Whip Mix, Louisville, Ky) in an acrylic ring (Mark V Laboratory, East Granby, Conn). A placement guide was used to align their buccal surfaces so that they were perpendicular to the bottom of the acrylic mold. The buccal tooth surface was cleaned with nonfluoridated flour of pumice (Moyco Industries, Philadelphia, Pa) for 10 seconds and rinsed with sterile water from an air/water syringe for 10 seconds. Transbond self-etching primer (3M Unitek, Monrovia, Calif) was used to condition the buccal surface of each tooth according to the manufacturer's recommendations. APC (Adhesive Pre-Coated) II Victory Series Twin premolar brackets (3M Unitek) were pressed to place on either the mesiobuccal or the distobuccal surface of each tooth, depending on which surface provided better adaptation with the premolar bracket. A plastic instrument was used to remove excess adhesive. The same operator (R.J.) placed all orthodontic brackets to minimize operator variability. Brackets were positioned so that the bracket/tooth interface would be parallel to the direction of the dislodging force. Orthodontic brackets were photopolymerized with 1 of 2 LED LCUs (Fig 1): L. E. Demetron (SDS/Kerr, Orange, CA) and Ortholux LED (3M Unitek). The teeth were randomly divided into 2 groups of 93 teeth each.

The first group of teeth and brackets was cured with the L. E. Demetron for 20 seconds. The second group was cured with the Ortholux LED for 20 seconds. Each