Use of Light Curing Units in Orthodontics: A Review

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Abstract

Introduction: Because of their wide field of applications, light curing units are now indispensable for any orthodontist or a general dentist, and hence it is very important to be familiar with the various types of light curing units, their history, specifications, advantages and disadvantages.

Methods: To find the articles appropriate for this systematic review, a search was conducted in the following database: PubMed (from 1966 to March 2010) using the terms “curing lights orthodontics” in the search box. Eligibility of the selected studies was determined by reading the abstracts of articles identified by the search. All the articles that seemed to meet the inclusion criteria of the systematic review topic were selected and the actual articles collected. The reference lists of the retrieved articles were also hand searched for any applicable studies that may have been missed in the database searches.

Conclusion: When selecting curing lights for an office, many variables need to be considered. Armed with knowledge about each curing-light category, orthodontists can evaluate their unique practice style and select the appropriate light or lights.

Keywords: Light curing units, Orthodontics.
Introduction

Since the discovery of the bis-GMA type of adhesive by Bowen, various methods of bonding orthodontic brackets directly to pre-conditioned tooth surfaces have been studied by Newman\(^1\), Mizrahi and Smith\(^2, 3, 4\), Retief, Dreyer and Gavron\(^5\), and Miura, Nakagawa and Masuhara\(^6\). Visible-light-cured adhesives, now used by the vast majority of orthodontists, were first described by Bassiony\(^7\) in 1978.

Materials and methods

Studies satisfying the following criteria were included in this systematic review:

I. Use of tungsten-quartz halogen curing lights, argon lasers, plasma arc curing lights or light emitting diodes for curing orthodontic resins.

II. Cross sectional and longitudinal studies.

III. Articles in English

IV. Articles published from January 1966 to March 2010

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History of curing lights

The light source first used for curing composite resins was an ultraviolet light (UV), which required 1 minute per millimeter of resin thickness for curing. The benzoin methyl ether component of composite resin was sensitive to light in the 340 nm spectrum. Because of safety concerns about the long term use of UV light, visible light curing (VLC) was introduced around 1980\(^8\). Compared with UV-cured resins, VLC resins were found to have a greater depth of curing. The curing of VLC resins is based on the presence of camphoroquinone, which is sensitive to light in the range of 460 to 480 nm wavelength spectrum, with an optimum at 468 nm.

The earliest visible light curing units used halogen bulbs. Their spectrum of radiation is continuous over the visible range, with radiation intensity increasing significantly towards the red end of the spectrum. Most tungsten-quartz halogen lights produce an energy density of approximately 400 mW/cm\(^2\), with a broad bandwidth between 400 and 520 nm. The halogen based curing lights are still popular in the market but despite their popularity, halogen bulbs have several shortcomings. These light curing units use most of their energy to heat a tungsten filament until it glows, creating light. Only 1% of the total energy input is converted into light; the remainder is generated as heat. The heat can cause blistering of expensive light filters and discoloration of reflectors. The cooling fan can be noisy and bulky. Halogen bulbs have a limited effective lifetime of approximately 40-100 hours and have to be replaced thereafter. Moreover, with a recommended curing time of 40 seconds per bracket, the light-curing time for bonding both the maxillary and mandibular
arches can approach 15 minutes which can be inconvenient. So, reducing the curing time became the next immediate goal for the developers.

The first attempt to reduce curing time was undertaken with argon lasers in the late 1980s. The purpose of these lamps is to increase the output light energy to an intensity that approaches 800 mW/cm² and to narrow the wavelength to approximately 470 nm. Independent research has verified that argon lasers can reduce the amount of light exposure, but to equal the bracket bond strength of a 40-second exposure to a conventional tungsten-quartz halogen light, the laser must cure the composite resin for 10 seconds. This is still a dramatic reduction in the required exposure time, from 15 minutes to 4. Nevertheless, the argon laser has several disadvantages. The laser units themselves are relatively large and expensive costing more than $6000; replacement bulbs are nearly $2000.

Plasma arc curing lights (PACL) were introduced in mid 1990s. The light cure source is a xenon gas that is ionized by 2 electrodes with a large voltage potential, to produce plasma. The emitted white light is filtered to a bandwidth of 450-500 nm, and the power density can reach more than 2000mW/cm². These lights were made to be as reliable as laser lights at a relatively lower cost ($3000-$4000). In contrast to lasers, plasma arc sources do not emit distinct frequencies but, rather, continuous frequency bands. However, these bands are much narrower than those of incandescent lights (halogen bulbs). Consequently, less filtering of undesired frequencies is required. Because of high intensity, the manufacturers say that 1 to 3 seconds of plasma irradiation cures many resin composites to a hardness comparable with that achieved after 40 seconds with conventional curing lights.

In 1995, Mills et al proposed solid-state light-emitting diode (LED) technology for the polymerization of light-activated dental materials. Instead of hot filaments used in halogen bulbs, LEDs use junctions of doped semiconductors to generate light. LEDs have a potential lifetime of over 10,000 hours and can be subjected to mechanical shock and vibration with very low failure rates. The latest blue LEDs use indium gallium nitride technology and can generate photons of a particular wavelength by varying the band gap. A wide band gap material produces high-energy photons near the blue region of the visible spectrum. As current flows through the semiconductor chips, electrical energy is converted directly into light, and little energy is emitted as heat. This results in a stable, efficient, long lasting output of blue light of 440 to 480 nm. The efficient energy conversion of the LEDs has allowed the development of cordless light-curing units that operate silently and have a very long life.

**Effect of curing times on shear bond strength**

Each of the curing lights produces a different light frequency and intensity, resulting in different curing times required for complete adhesive polymerization.

According to Lalani et al and Elvebak et al, at 300 mW power the argon laser has the capability to maximally polymerize the adhesive in as little as 5 seconds. Oesterle et al and Signorelli et al found out that xenon
plasma arc curing lamp exposure times of 6 to 9 seconds produced shear bond strengths equal
to those produced with 40 second exposures to
a conventional tungsten quartz halogen curing
light, in vitro. Silta et al16, Usumez et al17 and
Turkkahraman and Kucukesmen18 studied that
orthodontic brackets be photopolymerized for
atleast 20 seconds with the light emitting diode
light cure units before archwires are engaged
and that this is equivalent to 40 seconds of
halogen-based illumination. Based on the
above data it can be concluded that with
standard metal brackets, suggested curing
times for a complete cure are 15 to 20 seconds
on the mesial and distal of each bracket (total
40 seconds) using a halogen light, 10 seconds
mesial and distal (total 20 seconds) for LED
lights, 2-3 seconds mesial and distal (total 5
seconds) using an argon laser, and 3-4 seconds
mesial and distal (total 6-9 seconds) with a
plasma arc lamp. Recently, a new, high-
powered halogen light was claimed to achieve
ideal bond strength with only 6 seconds of cure
time19. Ceramic brackets require half of the
total time for each light type, and the light
source should be aimed directly through the
bracket20. Molar bonds require about 150%
longer curing times on each the mesial and
distal.

**Effect of light intensity on shear bond strength**

Elvebak et al13 compared the shear bond
strength produced by an argon laser at 4
different power settings (100, 150, 200 and
250 mW) and found out that brackets bonded
using the curing light of 150mW power
exhibited the highest bond strength.

**Effect of light guides and distance of light tip from the bracket on shear bond strength**

Bishara et al21 studied the effects of
using a smaller diameter light guide on the
shear bond strength of orthodontic brackets.
They concluded that the use of the Mini Turbo
Light Guide (diameter 4mm) did not seem to
significantly influence either the shear bond
strength or the bracket/adhesive/enamel failure
site as compared to a standard curved light
guide (diameter 11mm). However, Evans et
al22 studied the effects of using Power Slot and
Turbo Tip light guides and concluded that
these light guides with their collimation of
visible light to increase its intensity can be
recommended as advantageous alternatives for
curing composite resins for orthodontic
bonding procedures.

The distance of the light tip to the
bracket can decrease bond strength. With
increased distance, bond strength degrades
more significantly with LED lights than with
other curing lights; if access is difficult, a non-
LED light source should be considered.23

**Temperature rise**

Halogen, argon laser, and plasma arc
lights all generate significant heat and require a
cooling fan. All of these instruments therefore
generate significant noise during and after
operation. Although halogen lights have
powerful fans to cool the unit, the intense heat
does damage the light bulb so that the effective
bulb life is only about 100 hours.24 The
minimal heat generated by LED lights can be
easily dissipated by heat sinks, and these lights
can therefore operate noiselessly. Heat from curing units is transferred to teeth during bonding procedures; this can, at times, cause discomfort to patients. It is known that any increase in pulpal temperature exceeding 5°C to 6°C may result in irreversible tissue damage. Powell et al\textsuperscript{25} showed that in vitro pulp chamber temperature increase from laser units were significantly lower than that from the conventional curing lights. Tarle et al\textsuperscript{26} measured the temperature rise in the composite samples with three different light sources, and because of very short exposure time, they found a slight temperature rise with the high-power plasma light. Cobb et al\textsuperscript{27} and Powell et al\textsuperscript{28} concluded that argon lasers should pose no threat to the pulp if used at recommended energies. In fact, Powell et al\textsuperscript{25} stated that, at recommended curing times, in vitro pulp-chamber temperature increases from argon lasers were significantly lower than those of the conventional curing lights. Aslihan Uzel et al\textsuperscript{29} and Siddik Malkoc et al\textsuperscript{30} found in their study that halogen light induced significantly higher intrapulpal temperature changes than did the LED and PAC. However, orthodontic bonding with light-curing units did not exceed the critical 5.5°C value for pulpal health.

**Microleakage**

Asli Baysal et al\textsuperscript{31} studied the microleakage under bonded lingual retainers using high-intensity curing lights and found that little or no microleakage occurs at the composite/enamel interface with high-intensity light curing units. However, high-intensity light curing units allow more microleakage at the composite/wire interface and may not be safe for bonding of lingual retainers. Comparison of the results showed the least microleakage with quartz tungsten halogen (mean, 1.10 ± 1.05 mm) and the greatest microleakage with plasma arc curing light curing units (mean, 2.63 ± 1.49 mm). Serdar Arikan et al\textsuperscript{32} compared microleakage beneath ceramic and metal brackets photopolymerized with light emitting diode or conventional light curing units and observed microleakage along all bonding interfaces, regardless of the type of bracket or LCU used. The tested light emitting diode curing unit provided a reduction in chair time but caused more leakage between adhesive-bracket interface when metal brackets were used. However Mustafa Ulker et al\textsuperscript{33} found that the type of light-curing unit (Halogen, light emitting diode, plasma arc curing) did not significantly affect the amount of microleakage at the enamel-adhesive-bracket complex.

**Design considerations**

The energy efficiency and minimal heat generation of LED curing give them many characteristics that the other sources do not have. Because they use minimal energy and do not need a cooling fan, LED lights are able to be marketed as cordless units with a rechargeable battery. And because they do not have any moving parts or light filaments, they better resist vibration and shock.\textsuperscript{34} As there is no heat damage to the diodes, LED lights are effective for more than 10,000 hours of use with little output degradation. Although their exact mechanisms are unknown, argon lasers uniquely restructure enamel-surface characteristics, conferring some demineralization resistance when used for bonding. This protection increases synergistically with the protection imparted by fluoride.\textsuperscript{35}
Each of the various curing-light varieties has a different design. Plasma arc and argon laser curing lights are cumbersome and weigh between 9 and 15 pounds. Many owners of these lights mount the light on a rolling cart or dedicate a single chair for bonding procedures and leave the curing light there. Halogen lights occupy a small footprint and are often mounted chairside by each unit. Corded LED lights have similar space requirements to halogen lights, while their cordless counterparts can be left in any convenient location.

**Conclusion**

When selecting curing lights for an office, many variables need to be considered. Each practitioner needs to evaluate the infrastructure and patient flow of the office. Some orthodontists choose to have a light at each chair, while others are comfortable having one or two portable lights. The speed offered by plasma arc curing can be coupled with the portability of an LED light to move from chair to chair. Some practitioners choose to do extensive gingival recontouring, and a laser could provide both high-speed curing and hemostatic surgical potential. Other practitioners may object to fan noise and use LED exclusively. Armed with knowledge about each curing-light category, orthodontists can evaluate their unique practice style and select the appropriate light or lights.

**References**


