Photopolymerization of Composite Resin Using the Argon Laser

(Photopolymérisation de la résine composite au laser à argon)

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Sommaire

Comme la profession dentaire utilise de plus en plus de matériaux de restauration photopolymérisables, la recherche dans les sources de lumière qui font s’amorcer la polymérisation connaît une aussi grande croissance. Le laser à argon en est une source prometteuse, puisque la longueur d’onde de la lumière émise par le laser est idéale au déclenchement de la polymérisation des résines composites. On remarque dans la littérature une forte divergence d’opinion sur l’efficacité de la polymérisation au laser par rapport à la photopolymérisation traditionnelle. Les études révèlent que le laser à argon augmente la profondeur et le degré de polymérisation, réduit le temps de polymérisation et rehausse les propriétés physiques des résines composites polymérisées. D’après certains rapports, ces avantages sont contrebalancés par le fait que la polymérisation accrue au laser accentue le rétrécissement, la fragilité et la microinfiltration. Les dentistes qui s’intéressent à cette nouvelle technologie doivent suivre de près les progrès de ces études.

Mots clés MeSH : argon; composite resins; lasers

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Cet article a fait l’objet d’une révision par des pairs.

The first laser, a pulsed ruby laser, was developed by Theodore H. Maiman in 1960.1 Since that time, dental interest in lasers has been high and research has been continuing into ways to improve dental treatment through laser application.2 Since the early 1980s, one research focus has been the use of the argon laser for photopolymerization of composite resin restorative materials.3 This interest has arisen because the wavelength (488 nm) of light emitted by the argon laser is optimal for the initiation of polymerization of composite resins.4 Photo-activated composite resin polymerizes when the initiator (camphorquinone) in the resin is activated by light.5,6 Camphorquinone activation is initiated by a hue of blue light that has a wavelength within the range of 400 to 500 nm, with broad peak activity in the 480-nm range.3,7

Conventional visible light curing (VLC) units consist of white light with unwanted wavelengths filtered out,3 thereby producing a polychromatic spectrum of blue light. The resulting hue and brightness of the colour are of wide spectrum and low intensity, respectively. In research on composite-resin photopolymerization, VLC units can activate camphorquinone, but optimum curing power is not achieved, and the units often fail to meet the challenges presented by more complex resin restorations.8 Additionally, the hue and brightness parameters of conventional VLCs are not uniform over time. Bulbs, reflectors and light tips degrade, and filters become baked from heat generated by the units. As a result, the spectrum of light is slowly altered.8,9 These changes may result in a lack of predictability and consistency in restoration quality.

Unlike VLC units, the argon laser does not employ the use of filters. Instead, it generates one wavelength of blue light (i.e., the light is monochromatic) having a bandwidth of only 40 to 45 nm.4,10 In addition, the brightness of the light can be set to the manufacturer’s specifications for optimum efficiency, unique for each brand of composite resin. Some lasers can be calibrated before each cure, ensuring standard treatment for each patient. As with conventional VLC units, exposure time can be adjusted as necessary.

Laser photons travel “in phase” (i.e., are coherent), and are collimated such that they travel in the same direction.1,10 Less power is put out by the argon laser units than the conventional VLCs, yet they can cure the resin more effectively because the wavelength of the light is specific to the job being performed. VLC units emit wide bandwidths of 120 nm, resulting in a broad spectrum of wavelengths that overlap and are said to be “out of phase,” or incoherent.10 Two photons of incoherent light that are 180 degrees out of phase can cancel each other, resulting in decreased curing power and less polymerization of the composite resin. VLC units also produce a divergent beam of light, resulting in a loss of 40% of energy 6 mm from the curing surface. In contrast, the argon laser
emits a collimated (narrow, focused, nondivergent) beam focusing on a specific target, resulting in a more consistent power density over distance.\textsuperscript{4,8,11,12}

### Advantages

Because of the properties of the argon laser described above, the thoroughness and depth of composite resin polymerization are greater with this laser than they are when VLC sources are used. Less unpolymerized monomer is found in resins cured by argon laser compared to those cured with VLC units.\textsuperscript{8,11} This thoroughness results in the enhancement of certain physical properties of the laser-cured composite resin, including compressive strength, diametral tensile strength, transverse flexural strength and flexural modulus.\textsuperscript{4,8,11,13}

Wear resistance is equivalent when using either method of polymerization,\textsuperscript{14} but argon laser polymerization has demonstrated the potential to improve shear bond strengths in both enamel and dentin.\textsuperscript{15,16} Another study found no significant difference between bond strengths using argon laser and halogen lamp curing units.\textsuperscript{17} However, a significant difference was reported in bond strengths according to distance between the resin surface and the light source. The authors found that the laser-cured bond strengths did not decrease with increasing distance, whereas there was a significant decrease in halogen-cured bond strengths at distances greater than 0.5 mm. Furthermore, in all the above studies, the laser required less time to achieve equivalent or greater polymerization of the restorative material.\textsuperscript{4,8,11,13,15-17} One manufacturer claims that the argon laser needs only one-fourth of the exposure time: 10 seconds for 2 mm depth of cure compared to the 40 seconds recommended for VLC systems (Dentalaser Brochure 1998, Premier Laser Systems, Inc.).

Finally, from a practice marketing perspective, laser utilization may present an image to the public of an office dedicated to staying abreast of the latest technology. The perception of the lay public and patients' perception and acceptance of laser utilization in dentistry have been shown to be positive.\textsuperscript{2,18,19}

### Disadvantages

Although the size, weight and portability of newer argon laser curing units have improved greatly over the older ones, at approximately 20 pounds the unit is still fairly cumbersome and occupies considerably more space than a conventional VLC unit. The laser can generate a substantial amount of heat, the cooling fans tend to be noisy, and there is a 30-second time lag between turning the unit on and actual light emission.\textsuperscript{20} These shortcomings can be overcome, in part, with units now available that can be centrally installed, with curing wands radiating into individual operatories.

Because the technology in the dental office is still new, cost of the argon laser curing unit is a deterrent to its acquisition. Depending on the manufacturer, portable argon curing lasers range from $12,000 to $20,000, and central installation may incur additional expenses. Added to the cost consideration is the fear of rapid obsolescence in an arena of rapid technological change.\textsuperscript{21}

When laser light strikes a target, it may be absorbed, transmitted, scattered or reflected. When laser light is transmitted, tissue boundaries are crossed and tissues other than the target material are irradiated. Consequently, whenever a laser is used in the oral cavity, the dentist must determine the risk to surrounding tissues.\textsuperscript{12} When using the argon laser to remove intracanal debris in extracted teeth, Moshonov and others found that in dry canals after a few seconds it was impossible to hold the teeth between fingers because the root surface became too hot.\textsuperscript{22} Although power densities used by Moshonov were considerably higher than those used for photo-polymerization, the finding nonetheless points to the need for consideration of periodontal and pulp tissues.

It has been demonstrated, in vitro using extracted human teeth and in vivo in dogs, that there is a temperature rise in the dentinal roof of the pulp chamber as well as within the pulp itself when an argon laser is used to cure composite resin in cavity preparations.\textsuperscript{23,24} However, the peak temperature increases within the pulp chamber were believed to represent no significant pulpal risk when using the low limits of laser energy recommended to cure composite resin. There is little chance of leaving the laser on the tooth long enough to damage the pulp.\textsuperscript{24} It has been shown, however, that extended curing times can have deleterious effects on the parakeratinized gingiva of dogs. When 10-, 20- and 30-second exposure times were tested, minimal effects were noted following the 10- and 20-second exposure times, whereas necrosis, disruption and vesiculation were noted five days after application of 30-second exposures.\textsuperscript{25}

Short-wavelength light is more energetic than long-wavelength light.\textsuperscript{10} The argon laser beam is in the short-wavelength blue light spectrum, which has the highest energy photons of any wavelength of visible light. Its energy level is only slightly less than that of ultraviolet light, which has a well-documented history of posing a biohazard. Consequently, extreme care must be exercised to avoid direct exposure of the patient’s eyes, as exposure could result in immediate visual damage. Additionally, concern has been expressed that indirect exposure by reflection could also harm the operator’s eyes over time.\textsuperscript{26}

Although there are numerous reports of enhanced physical properties of laser-polymerized composite resins, there are conflicting reports about the marginal seal obtained with argon laser curing. Increased shrinkage and brittleness of some small-particle resins has been reported when they have been cured with a laser.\textsuperscript{20} No significant change was shown in linear polymerization shrinkage in one in vitro study,\textsuperscript{27} and another study showed that laser-cured pit and fissure sealants demonstrated a superior seal to those cured with visible light.\textsuperscript{28} However, Class V composite restorations in extracted primary and permanent human teeth showed a higher degree of microleakage in the laser-cured group compared to the light-cured group. These differences were significant using a dye leakage measurement but not significant using an isotope leakage measurement.\textsuperscript{29} Another study investigated the possibility of obturating root canals using argon laser-cured composite resin. SEM evaluation revealed resin penetration into tubules; however, the
observation of tears and gaps between resin and canal walls led
the authors to suggest that polymerization shrinkage affected
dentin adhesion. A possible explanation for these conflicting
results is that a durable composite dentin bond can be formed
only on flat surfaces or in very shallow cavities. In other situa-
tions, the polymerization contraction will disrupt the dentin
bond. O ne author suggests that this disruption could be
attributed to the increased penetration and heat of the laser,
which results in both a greater degree of polymerization and a
higher degree of polymerization shrinkage compared to
conventional light curing.

Pulsed argon laser curing may be the solution for the
shrinkage problem. Pulsing, or periodic interruption of the
laser beam, can be precisely controlled in nanoseconds. The
theory is that interruption of the beam allows the target mate-
rial to cool between laser pulses, thus preventing overheating.
Two studies have shown promising results in reduced poly-
ermerization shrinkage however both studies compared a
nano-pulsed blue dye laser and a continuous wave argon laser.
Since the dye laser is a completely different instrument from
the argon laser, it is difficult to conclude whether their results
were due to pulsing of the laser beam or use of a different laser.

Recent research on the influence of light intensity has sug-
gested that the more rapid rate of cure obtained by high-inten-
sity curing does not allow enough time for stress relaxation by
flow of partially cured material. In vitro results with conven-
tional VLC units have shown that the use of high-intensity
curing has a negative effect on the marginal integrity of the
final restoration. However, light-initiated prepoly-
ermerization at low intensity followed by a post-light-cure at full
intensity (soft-start polymerization) significantly improved the
marginal integrity of light-cured composite fillings.

If these results can be extrapolated to the argon laser, per-
haps the greater depth of penetration and intensity of the laser
beam result in a rapid polymerization with no chance for stress
relaxation. Pulsing the beam may lessen this disadvantage by
allowing the partly cured resin to flow and thereby reducing
overall shrinkage. However, the intensity of the pulses remains
the same. It may be beneficial to prepolymerize at a lesser
intensity or with a conventional light source to reduce poly-
ermerization shrinkage. At the very least, this finding illustrates
the reality of rapid changes in laser dentistry technology and
the need for further research.

The reported enhancement of physical properties achieved
by laser polymerization may become less significant with aging
of the cured resin. When diametral tensile strength values for
a hybrid resin were compared over time, argon laser activation
resulted in higher early values than conventional visible
light curing, but these differences essentially disappeared at
20 days.57 Because the reaction of polymerization continues
after initiation, the samples cured with the VLC units increased in strength over the 20-day period.

Clinical Significance

As dental technology continues to evolve, new methods of
performing certain dental procedures will continue to replace
those once thought as the pinnacle. The argon laser may be
one such example. Its use in polymerizing composite resins
clearly demonstrates an immediate higher degree of polymer-
ization than is obtained with VLC units. This enhanced
polymerization is reflected in the resultant improvement in
physical properties and bond strengths.

Although the enhancement may be a temporary effect, it
may nonetheless have important clinical implications in pre-
vailing early restoration failures. Not only is early maximal
polymerization important to avoid retention failures, it is also
important in reducing adverse pulpal responses to unpolymer-
ized monomer. It must be noted, however, that reports of
decreased pulpal sensitivity when curing composites with the
argon laser are anecdotal only.

The reduction in polymerization times provided by the
argon laser may prove beneficial in reducing chairside time and
achieving patient satisfaction, especially with restless children.
It could also be helpful in situations where maintenance of a
dry field for any length of time is difficult. Also, in cases where
it is impossible to place the light wand in close proximity to
the restoration, the laser beam offers the advantage of no loss
of power over distance, as is suffered by the VLC unit. The
increased penetration depth of the argon laser may make it
possible to cure thicker increments satisfactorily or to cure
through thicker sections of tooth. It could also make it possi-
bile to control the direction of polymerization shrinkage by
curing through the tooth. These advantages may make the
argon laser an important tool when placing restorations that
are complicated or in hard-to-reach areas. On the other hand,
the narrow, focused beam of the laser may make angulation of
the handpiece more critical in areas of compromised access.

The argon laser can be used to initiate polymerization in
any of the currently used light-activated restorative materials.
In addition to restorative composite resins, this growing fami-
ly includes bases, liners, pit and fissure sealants and impression
materials. Therefore, the argon laser may prove to be quite
versatile clinically.

The question of marginal leakage is a serious one. If exces-
sive polymerization shrinkage offsets the benefits realized by
using the argon laser, then there is no overall gain. In fact, a
negative effect may result. If polymerization shrinkage can be
reduced only by using a lesser intensity over a longer exposure
time, then no time benefits are realized. If polymerization
shrinkage is reduced only by using a different laser, then there
is a heavy financial penalty for trying to stay abreast of tech-
nology. To justify such an expensive piece of dental equipment,
lontitudinal studies must be closely followed. In the mean-
time, clinicians should keep up to date about this new tech-
nology and critically evaluate the current literature before
making an irreversible decision.

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