Review Article

Ocular Hazards from Use of Light-emitting Diodes in Dental Operatory

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Abstract

Most of the modern dental setups are flooded with high-intensity lights. Light-emitting diodes (LEDs) being a high-intensity illuminator are fast gaining popularity among dental practitioners. Clinicians are using LED headlamps, overhead LED illuminators, LED curing units, and fiber-optic dental handpiece along with magnification loupes and microscopes. These LED illuminators have a strong blue-light component, which can cause serious retinal damage if used for a longer duration of time. Although the ocular hazards of these high-intensity lights have been reported in the literature, most of the dental practitioners are unaware of it. This review aims to highlight the possible ocular hazards from usage of LED in dental operatory and methods to minimize the potential hazards.

Keywords: *Age-related macular derangement, blue-light hazard, dental lights, light-emitting diodes, ocular hazards*

Introduction

In contemporary dental practice, safety aspects should be the topmost priority to avoid injury and possible litigations. In all dental procedures, the principle of "do no harm" should be strictly followed. Dentists must also be vigilant about their personal protection to safeguard their health. It is the duty of the dentist to ensure safety of himself, his coworkers as well as his patients. Most of the modern dental setups are flooded with high-intensity lights. Light-emitting diodes (LEDs) being a high-intensity illuminator are fast gaining popularity among dental practitioners.

Although the ocular hazards of these high-intensity lights have been reported in the literature, most of the dental practitioners are unaware of it. This review highlights the possible ocular hazards from usage of LED in dental operatory and proposes the possible guidelines to minimize the potential hazards.

What is an Light-emitting Diode?

An LED is a semiconductor diode, which emits light in the visible spectrum in a narrow range of wavelengths, resulting in virtually monochromatic light.[1] High-brightness LED is produced when complementary wavelengths (short/blue and long/green) arrive on human eye simultaneously to give white-light sensation. LEDs are not inherently white-light sources, and a blue-light component is always present in the LED spectrum similar to white-light sources.[1]

What is Visible Light?

Visual perception is possible when radiation within a wavelength of 400–700 nm reaches the retina, where peak sensitivity is at 555 nm and is near zero below 400 nm and above 700 nm. Optical radiations are ultraviolet radiation (100–400 nm), visible light (400–700 nm), and infrared radiation (700–10,000 nm). Visible light is further divided into short-wavelength radiation which is blue, medium-wavelength radiation which is green, and long-wavelength radiation which is red.[2]

Sources of Light-emitting Diode Lights in Dental Operatory

Uses of high-intensity illumination through LEDs are gaining popularity with dentists. Practitioners are using LED headlamps together, overhead LED illumination, fiber-optic dental handpieces, magnification loupes, surgical microscopes, and LED curing lamps for polymerization of

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light-cure composites. Concerns have been raised regarding the ocular hazards of the multiple LED light sources used in dental clinics because of the constant presence of blue-light component in the LED light.

Hazards of Light-emitting Diode Light

All white-light sources have a blue-light component, but the blue-light component of natural light is weaker than the green light. The main safety issue of LED headlights is that the blue-light component is too strong compared with the green light. Retinal damage can be caused by light, particularly blue light, by photochemical process which has been proved in research done around five decades ago. Photoretinitis is the serious retinal damage that results from exposure of the retina to shorter wavelengths in the visible spectrum (violet and blue light), which may further worsen to cataractogenesis and transient or permanent opacification of the lens.[3]

Blue-Light Hazard from Light-emitting Diode

Blue-light hazard (BLH) is defined as the potential for retinal injury due to high energy short-wavelength light. This blue light with a short wavelength of 400–500 nm at very high intensities can cause the destruction of photopigments to release free radicals. These free radicals can further cause irreversible oxidative damage of retinal cells, eventually resulting in blindness.[4]

Irradiance occurs when a light source radiates a surface that is indirectly viewed by an operator and not by directly gazing into the light source. In an LED, the brightness (expressed as radiance or luminance) may be extremely high.

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended a threshold limit with the International Commission on Nonionizing Radiation Protection guidelines for BLH of 100 j/cm^2 over a total viewing time of 167 min in an 8-h day for individuals with normal photosensitivity.[5] For patients and dental personnel who have undergone cataract surgery or are on photosensitive medications, the threshold limit is even lower as retinal damage can occur with shorter exposure times.

Age-related Macular Derangement

Visual impairment of the central visual field (macula) that occurs predominantly in elderly people is called age-related macular derangement (ARMD). This occurs commonly in elderly people.

Studies in animals have proved that long-term exposure to short-wavelength light is a strong factor that predisposes to senile macular degeneration.[6] The human eyes also may develop ARMD from long-term exposure to visible light.

Blue light gets transmitted through the ocular media and is absorbed by the retina. High levels of blue light cause immediate and irreversible retinal burning. Accelerated retinal aging and degeneration may result from chronic exposure to low levels of blue light. This may result in chronic photochemical injury to the retinal-pigmented epithelium and choroid accelerating ARMD.[7]

Protective Mechanisms of the Eye

The main protective mechanisms of the eyes are absorption of harmful wavelength, adjustment of pupil size, and aversion response of the eye to bright light.

Lens of the eye absorbs wavelengths under 400 nm, preventing damage to the retina. Bluer spectrum radiation can reach the retina more in a younger eye than the aged eye. In the young eye, ocular transmittance is high, reaching close to 90% at 450 nm. However, the eyes have a very effective antioxidant system that protects its damage from intense ambient light. However, after middle age, the production of antioxidants decreases.[8] This suggests that LED lights should be used with caution if practitioner, supporting personnel, or patients are above middle age.

Cataract: when the lens of eyes turns yellow due to cataract, the lens serves as a blue-light filter, i.e., a natural protection for the retina as age increases. Patients and practitioners who have undergone cataract surgery and children are more sensitive to blue light than healthy adults.[9] Therefore, LED illumination should be done with caution in clinics where stakeholders have undergone cataract surgery.

Aversion response to bright light is another protective mechanism of the eye wherein eyes move automatically from a bright light. This generally limits single exposures to <0.25 s. LED units emit a narrow band of blue-light radiation, and this does not always evoke this protective aversion response. This also augments the ocular hazards of LED light.[10]

Cumulative Effects of Light

Cumulative effect of light exposure in retinal damage was demonstrated by Noell *et al*. They showed that a 5 min exposure does not produce a significant effect, whereas three and four exposures each of 5 min and each followed by a 1-h dark interval led to significant damage. Dose fractionation versus continuous irradiations without interruptions have proven that the former produces more severe effect than the latter.[11] Dental practitioners using LED illuminations, who move from patient to patient during the workday, should be aware of this.

Glare

Glare does not impair visibility but causes discomfort. Light scattering causes a disability glare that creates a veil lowering contrast impairing visibility. A veiling glare is produced by all high illuminative light sources. LED lights with a high content of blue are liable to generate glare. The use of water in the dental operating field increases reflection and glare for the operator. This is of concern when multiple light sources such as overhead lights, operating lights, and reflecting mirrors are used to illuminate the area of operation.

Magnification

The principle of conservation of radiance (brightness) states that the source radiance and retinal irradiance will not be increased by the use of optical aids.[12] Even though there is no increase in retinal irradiance, the increasing size from the use of optical aids may increase the retinal damage as a consequence of the spot-size dependence of retinal thermal injury.[12]

Light-emitting Diode Dental Headlamps

The LED headlamps are of three types: (i) neutral: emits blue spectrum similar to green spectrum, (ii) cool LED: blue spectrum slightly stronger than green spectrum, and (iii) extremely cool-blue spectrum much stronger than green spectrum.[1]

Long-duration exposure to cool and extreme cool LED lights may be harmful to the eyes. Extreme cool LED lights with elevated blue spectrum distort colors.[1]

The uniform beam without color distortion without bright spots or color separation generated by achromatic multilens optics is the safest. The beam formed using single-lens optics is the most dangerous because the strong blue spectrum is visible to the eyes.[1]

Ocular Safety of Light-emitting Diode Light-curing Devices

Safety studies conducted in 1980s using quartz tungten halogen (QTH) lamps found that these units have little potential to cause ocular injury. However, the units tested were delivering <400 mW/cm^2 over abroad spectrum between 400 and 500 nm.[13]

However, the present-day light-curing devices made of QTH, high-power plasma arc (PAC), and LED curing lights may deliver much higher irradiances up to 5800 mW/cm^2 with peak emission close to 440 nm. Studies have found that, with these units, ACGIH limits may be reached during an 8-h workday. An operator not wearing orange protective glasses, looking at the light tip for the 1st s of each curing cycle before looking away, may need only seven light exposure cycles to exceed the maximum permitted exposure with the tested PAC light.[14]

Blue-light filtering glasses ("orange blue blockers") reduce the transmission of light below 500 nm to <1%.[15] Hence, with these glasses, it is safe for the operator to watch what they are doing when light curing.

Conclusions

Dental practitioners are at a great risk for light-induced retinal damage, especially due to the current setup of dental clinics where there is a surge in LED usage. Potential risk factors are as follows:

1. Blue light (blue-wavelength component of the light)
2. Use of high-intensity light sources
3. Longer duration of exposure to these light sources
4. Use of magnification aids such as dental loupes and surgical microscopes, which results in magnification of light
5. Increased reflection or glare of light
6. Increasing age of the practitioner
7. History of cataract surgery.

Guidelines to minimize potential hazards due to use of LED lights in dental operatory are as follows:

1. Lights with strong blue light that tend to distort the color of objects should be avoided
2. If there is dispersion of color by LED, then it should be discarded
3. LED headlight with strong glare should be avoided
4. Brightness of the overhead operatory light should be set to an optimum/minimum brightness level such that minute details can be seen
5. Set the LED headlight at an optimum/minimum brightness level which allows you to see details
6. Protect the eyes of everyone in the operatory that could be exposed to bright light with appropriate orange (blue-light blocking) safety glasses.

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Conflicts of interest

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