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REVIEW

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Health hazards associated with curing light in the dental clinic

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Abstract The assessment of side effects of substances encountered in odontology by patients and the dental team must include the direct and indirect effects of irradiation emitted from polymerisation devices. The eyes of the lamp operators are at risk from acute and cumulative effects, mainly due to back-reflection of the blue light. Furthermore, phototoxic and photoallergic reactions originating from absorbed radiation in endogenous or exogenous substances accumulated in the operators' eyes and skin (hands) as well as the patients' oral mucosa must also be taken into consideration. Preventive measures include reading the manufacturers' operating instructions for curing devices and using radiation-filtering protection goggles.

Keywords Eye damage · Photosensitivity · Polymerisation lamps · Occupational hazard

Introduction

Curing light is employed in many aspects of modern dentistry. Modern techniques in cavity restorations, veneer- and orthodontic bonding and fissure sealing, etc., all depend on in situ polymerisation of monomers, most often brought about by light activation. Techniques of this kind include the use of chemically active substances such as acids, solvents and a series of different monomers, representing a potential risk of side effects for patients and dental personnel. The curing light is an important factor in this context because photoinitiators in primers, adhesives and other materials [9, 23] absorb UV and visible light and can give rise to photosensitising reactions. In addition, leachables and degradation products from the dental materials as well as residuals from oral hygiene products and drugs may have radiation absorbing properties and, hence, may contribute to or be responsible for photoactivated reactions. The intention of the present paper is to give an outline of the physical and biological factors that may lead to side effects associated with curing light. Special attention is paid to the operators' eyesight.

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Physical characteristics of curing light sources

Different curing lamps have different emission spectra within the electromagnetic 350–550 nm spectrum and have different intensity. The polymerisation effect is obtained, in most cases, by way of the photoinitiator camphorquinone, in itself an allergen. The emission range of halogen lamps is 350–550 nm with peaks between 470–490 nm in the blue and blue-green light region, and a light intensity of at least 0.4–1.1 W/cm^2 [3, 7]. The intensity of halogen lamps could be as high as 10,000 times that of sun radiation within certain wavelength ranges in the visible light region [19]. Most plasma arc light lamps and light-emitting diode (LED) lamps have a more narrow wavelength interval. Many of them have no UV component, although a new LED lamp is now on the market with a 400-nm peak in addition to a 450-nm peak [4]. There are plasma arc lamps currently available with spectral ranges from 380 nm [10]. These plasma arc lamps have a higher intensity and older LED lamps have a lower intensity as compared with halogen lamps [19]. According to the manufacturers, newer LED lamps have the same or even higher intensity compared with halogen lamps. At present, the majority of curing lamps in the dental clinic are of the halogen type, with some radiation in the UVA range. It is the subjective experience of the authors that the trend for newly developed curing lamps leans toward LED lamps.

Photosensitisation: Phototoxic and photoallergic reactions

Photosensitisation is the term used for reactions dependent on the presence of certain photochemicals and the action of optical radiation in the 320–800 nm range. The adverse reaction is brought about by visible light or UV induced excitation involving free radicals or reactive oxygen species. These substances as well as any irritants and toxicants produced may cause damage to biomolecules. Photosensitised reactions are divided into phototoxic and photoallergic reactions. Only 10–20% of the photosensitised reactions are estimated to be of the allergic type. In contrast to the phototoxic types, they are seldom evoked by systemic agents [5]. The mechanism of reaction is similar to that of allergic contact dermatitis, but absorption of irradiation is necessary for the formation of antigens. Photoallergic reactions usually occur within 24–48 h. Phototoxic reactions occur within minutes to days and at higher doses of the offending chemical and radiation. In contrast to photoallergic reactions, the phototoxic reactions can occur on the first exposure. The clinical morphology also differs between the two pathways of photosensitivity.

Photosensitisers can be of endogenous origin such as porphyrins and flavins, or exogenous such as those derived from tar, vegetable and plant products, and fragrance materials. In addition, a number of commonly used drugs are potential photosensitisers, e.g. antidepressants, anticancer drugs, antimicrobials, antipsychotics, diuretics, oral contraceptives and others [5, 21] (a "Hibanil hat" was the popular term for a sunlight-protective head-gear used by psychiatric patients on chlorpromazine. Hibanil: Chlorpromazine). However, due to the difficult distinction between phototoxicity and photoallergy with regard to systemic agents, these reactions are often termed photodrug reactions. Two examples of photodrug reactions are cited here: 1) A generalised, intensely erythematous eruption on the face and the submental area, which was attributed to a combination of long-term antimicrobial medication (trimethoprim) and exposure to stray light from a laboratory photocuring unit [11]. 2) A 67-year-old woman experienced an erythematous rash on sun-exposed skin within the third week of treatment with a gargling solution containing benzydamine hydrochloride for pharyngitis [8]. Several cases of photocontact dermatitis have been reported after either topical or systemic treatment with this drug [8]. Other photoactive chemicals are employed as therapeutic agents, e.g. 8-methoxypsoralen for phototherapy of psoriasis (PUVA) and porphyrin-derivatives administered in photodynamic therapy (PDT) of cancer and actinic keratosis.

Photoallergy is diagnosed by patch testing combined with the appropriate irradiation source. A photoallergen test panel according to the North American Contact Dermatitis Group contains 27 substances such as p-aminobenzoic acid (UVB-blocking substance previously used in sun lotion), chlorpromazine (antipsychotic), chlorhexidine (antiseptic and disinfectant), hexachlorophene (antiseptic), triclosan (antibacterial substance used in some toothpastes), etc. [5]. The irradiation source is kept within the UVA spectrum and the dose of radiation below the level inducing erythema, i.e. less than approximately 20 J/cm^2. Almost all chemical photosensitisation reactions have their action spectra within the 320–400 nm range (UVA) and in the visible range, 400–800 nm [5], depending on the absorption spectrum of the photosensitiser. Since resin based materials are polymerised by photoenergy, it is of interest to discuss potential adverse effects associated with the use of curing lamps for patients and dental personnel. Such effects could be photosensitivity reactions or possibly thermal effects.

Potential oral tissue and dermal effects

Active use of curing light in operative dentistry may take hours per day. Depending on the angle of the light beam, the distance to the light source and the lamp spectrum, part of the radiation is absorbed by the target organ, some is scattered to neighbouring structures, and some is reflected. It is assumed that 10–30% of the curing light is reflected towards the operator [14]. A possibility of enhanced reflection resides in the use of oral mirror or strips during the curing process, while a dark-coloured rubber dam may represent a reduced reflection. Potential soft tissue side effects of scattered and reflected light depend on the wavelength, the time and the intensity of the irradiation exposure. The UV component of halogen lamps must also be considered in an assessment of cataract development and direct irradiation effects on cells.

Physical data from different curing lamps do not indicate that exposure from curing lamps during normal use and a normal day would reach threshold limit values (TLV) for blue light on skin [1]. However, the UV fraction of the lamp with highest intensity applied close to the operator's skin would reach the TLV in 11 min [19]. These limits are set for occupational exposure for workers not vulnerable to photosensitivity. If workers suffer from photosensitivity diseases or are taking photosensitising drugs, these limits do not apply. A study on UV absorption efficiency of gloves shows that latex gloves absorb 76% of UVA while vinyl gloves absorb only 33% of the radiation [12].

The oral tissues are not uniform structures in the sense that the thickness of the epithelial layer, the keratinisation, the vascularisation, and the hydration differ from site to site. These factors may represent differences compared to skin with respect to light absorption, scattering and reflection. However, information from the dermal model is probably the best estimate for radiation hazards to oral soft tissues at present. Operating instructions for curing lamps may contain warnings against irradiation of oral soft tissues for fear of causing damage or irritation (see later).

It is accepted that allergic sensitisation by way of mucosal exposure is more difficult to accomplish than by dermal exposure, presumably because of the difference in the concentration of Langerhans cells. In addition, a delayed reaction is not as easily provoked on the mucosal surface as on skin. Epidermal tests are therefore used also for intraoral reactions. However, it is not thoroughly investigated whether photosensitised reactions may be induced differently in the mucosa than in skin. The oral mucosa has experienced less evolutionary tolerance to reactions evoked by radiation and, hence, repair mechanisms may not have been developed to the same extent as in skin.

Experimental data indicate that oral exposure to curing light is accompanied by a T-cell induced inflammation. An adhesive also increased the T-cell number, but the combination adhesive/light exposure did not increase this response [2], probably due to a shielding effect by the polymerised adhesive. Although more scarce than in skin, the fact remains that melanocytes and immune-presenting cells are present in the oral tissues and that exogenous irradiation-absorbing molecules originating from food, various oral hygiene products or medications and corresponding endogenous molecules (hemoglobin, riboflavin, DNA) are accessible to the curing light. Some of the suspected allergic reactions where the allergen is not found might therefore be attributed to photoallergic reactions.

Normally, thermal effects are not expected in either tissue because the temperature of the curing process does not reach a level leading to tissue coagulation. However, heat transfer from the irradiated area is a factor of major importance in influencing the temperature rise caused by irradiation. Heat transfer is dependent on the vascularisation, which varies with age and the quality of tissues, such as in the tooth pulp [3]. Depending on the vascularisation, 100 mW/cm^2 is a typical thermal threshold irradiance for long-time irradiation, which will take several minutes to cause a thermal increase.

Potential effects on eyesight

Adverse effects on the eyesight are the most important aspect of biological injury from curing radiation, either as a direct, accidental eye exposure or as cumulative effects of scattered radiation following unprotected use of curing lamps. This phenomenon is explained by the anatomy and the function of the eye. Visible light reaches specified photoreceptors in the retina that may be subject to photochemical injury if the intensity of the radiation is high enough. The blue-light retinal injury is comparable to the injury following direct exposure to ecliptic sunlight (solar retinitis). Harmful effects of this kind are seen by short radiation exposure with high intensity, or by moderate exposure during prolonged time. The harmful effect may appear after several days and may continue for weeks. In severe cases permanent retinal injury is perceived as a blind spot in the centre of the visual field. Besides, it is assumed that blue-light exposure amplifies aging and degenerative processes in the eye [6, 13]. Thermal harm is not considered to contribute to such injuries.

The short-waved radiation of the optical spectrum, UV, is absorbed by the cornea and the ocular lens and does not normally reach the retina. The exception is UVA radiation in small children and in patients having their lens removed due to cartaract surgery before the new lens is in place [20]. However, the absorption of UV radiation may result in adverse corneal reactions. Transient injury of the cornea, photokeratitis, is seen after exposure to UV radiation in the 180–400 nm range. A corneal condition of this kind is known as snow blindness if the injury has been provoked by snow-reflected sunlight; it normally disappears within 48 h. However, the possibility of permanent injury after repeated exposures has been discussed [16, 20]. Another hazard connected with the UVB component (280–320 nm) of sunlight is the development of cataract, often hitting elderly individuals in Nordic areas. Biochemical studies indicate that UVA radiation (320–400 nm) also contributes to the aging of the ocular lens and age-related cataractogenesis [17, 25]. Furthermore, the vulnerability of the eye towards irradiation increases after middle age due to accumulation of endogenous irradiation absorbers and a decrease in the production of antioxidants [18].

Photosensitivity can be induced in the eye if a radiation-absorbing substance such as a drug, a dietary supplement or a diagnostic dye binds to ocular tissue and is exposed to intense irradiation of wavelengths absorbed by these substances. Examples of such phototoxicity of the eye occur with the use of certain antimalarial drugs [15] and the over-the-counter antidepressant medication St. John's Wort [24].

Implications for curing light radiation

Maximal exposure time with respect to occupational blue-light injuries and general UV exposure of the eyes has been estimated for 13 dental curing lamps on the basis of data on spectra and intensity [19]. In the calculations, a 30% reflection of curing light radiation and a distance of about 30 cm between the dental operation site and the operator's eye were assumed. The calculations were performed according to the exposure limit guidelines set by the American Conference of Governmental and Industrial Hygienists (ACGIH) and the International Commission on Non-Ionising Radiation Protection (ICNIRP). Blue light maximum for the eye was estimated to about 1 min/day for reflected light, whereas a direct (accidental) blue-light exposure with zero distance from the eye should not exceed 1 s. This maximum was also true for the UV component of halogen lamps. The reflected UV component from halogen lamps did not exceed the exposure limits for eye or skin exposure.

Information from operating instructions

The operating instructions accompanying curing lamps illustrate the potential adverse effects from light exposure. Extracts of the operating instructions for the Elipar Trilight LED lamp (ESPE) are cited here:

- Irradiation must not be directed towards the eyes, illumination must be restricted to the area of the oral cavity in which the clinical treatment is intended.
- Irradiation of soft tissue should be avoided as excessive exposure to high-intensity light may cause damage or irritation. If applicable, cover such areas.
- Do not use in patients with a history of photobiological reactions—or who are currently on photosensitising medication (including 8-methoxypsoralen or dimethylchlorotetracycline).
- Individuals with a history of cataract surgery may be particularly sensitive to the exposure to light and should be discouraged from Elipar Trilight treatment. Treatment is appropriate if special safety measures such as the use of protective goggles to remove blue-violet and UV are undertaken.
- Individuals with a history of retinal disease should seek advice from their ophthalmologist before operating the unit. This group of individuals must take extreme care and comply with any and all safety precautions (including the use of suitable light filtering safety goggles).
- The low maximum time for direct (accidental) UV/blue-light eye exposure strongly suggests that any curing lamp should be shut off at all times when not actively used.

Prevention of adverse radiation effects on eyesight

The maximum blue-light exposure of 1 min/day cited above to avoid adverse eyesight reactions refers to a worst case situation using halogen lamps, and is not valid for all curing lamps. On the other hand, the more intense blue-light radiation of plasma lamps as well as newer LED lamps may lead to even shorter maximum exposure time. However, details of this kind are academic in the discussion of blue-light hazards in the dental clinic because considerably more "curing time" per day is needed to complete the curing procedure anyway. Eye protection in the form of UV- and blue-light filtering goggles, not sun glasses, is therefore necessary for dental personnel. Ordinary prescription glasses do not prevent UV or blue-light penetration. Artificial contact lenses do not offer sufficient protection because they may lose their filtering characteristics over time or may allow penetration of some radiation in the blue and UV range even if they are declared to have UV filters [22]. It is essential for dental personnel to make sure that the cutoff range of protective glasses as declared by the manufacturer is adequate for the intended function.

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