An insight into the effect of ultraviolet radiation: from promotion of skin malignancies to use in dentistry

Gag O.[1,2], Rivis M.[1], Dinu S.[1], Chioran D.[1], Stana H.A.[3], Popovici R.A.[1]

[1]*Faculty of Dental Medicine, "Victor Babes" University of Medicine and Pharmacy from Timisoara*
[2]*Department of Dentistry, Faculty of Dental Medicine, "Vasile Goldiş" Western University of Arad, Romania*
[3]*Department of General Medicine, Faculty of Medicine, "Vasile Goldiş" Western University of Arad, Romania*

Correspondence to:
Name: Rivis Mircea
Address: Revolutiei 1989 Bvd, No. 9, Timisoara, Romania
Phone: +40 722 287 582
E-mail address: rivis.mircea@umft.ro

Abstract

Exposure to ultraviolet radiation (UV) can occur either naturally - through exposure to solar radiation, or synthetically - through exposure to various devices that emit ultraviolet radiation. As far as the oral cavity is concerned, the oral cells meet solar ultraviolet radiation once the mouth is opened or with ultraviolet radiation applied with the help of devices used for diagnostic or treatment purposes in dental procedures.

Ultraviolet radiation is on the list of recognized carcinogens (WHO, 2009) and specialist studies have highlighted the fact that oral cells are much more sensitive to these radiations than skin cells. Considering these premises, the current study proposes to highlight the effects produced by ultraviolet radiation, through the prism of its use for diagnostic and therapeutic purposes in the field of dental medicine, but without neglecting the negative effects produced on the skin, the first defense barrier of the human body against harmful factors in the environment. At the same time, the connection between the damage of oral tissues due to exposure to environmental ultraviolet radiation and the state of knowledge in the field regarding the effectiveness of the use of UV in the newest techniques in dentistry is analyzed.

Keywords: oral cavity, ultraviolet rays, tumor cells, carcinogenic effect

INTRODUCTION

The general health implications of exposure to ultraviolet radiation (UV) are dependent on the type of radiation, dose, and exposure time. Of clinical importance are type B ultraviolet radiation (range 280-315 nm) and type A ultraviolet radiation (315-400 nm) [1]. Solar UV type B radiation is mainly responsible for inducing erythema and increasing melanin content (producing tanning) [2]. These clinical, acute effects can also be produced by UV type A radiation if the physical doses (expressed in J/cm^2) administered are approximately a thousand times higher [3].

Ultraviolet radiation produces immunosuppression, the consequences of which are not fully known, but which play a central role in the initiation of malignant diseases [2,4]. Overexposure to ultraviolet radiation can weaken the immune system, an effect that simultaneously weakens the skin's role as a barrier against harmful agents [2]. Regarding the differences between ultraviolet radiation of natural origin and those of artificial origin, it should be specified that there are no intrinsic differences in terms of physical properties, but there may be differences in the spectral profile which, in turn, may produce biological effects. The comparison between the acute effects produced by natural radiation and artificial radiation is relatively easy to achieve, while the comparison between the chronic effects represents a challenge for specialists in the field [2,5]. Tanning devices for cosmetic purposes have sparked a series of controversies since both positive and negative effects have been recorded following their use [6]. Regarding the positive effects, besides obtaining the desired cosmetic effect (tanning of the skin), achieving a state of well-being, even improving the status of vitamin D (although the data in this regard are quite limited). Regarding the negative effects, these devices are associated with the development of malignant melanoma, respectively ocular melanoma [2,6].

The biological effects exerted by a certain emission spectrum have a relevant importance compared to the specific irradiation (the wave bands that represent physical parameters) [7]. The effective dose in terms of the biological effect is achieved after weighting a given emission spectrum with the relevant action spectrum. This relevant spectrum of action should be the spectrum of action of human erythema, known to be like the spectrum of action that produces the tanning effect but also to the spectrum of action that leads to the development of squamous cell carcinoma [2].

Therefore, the irradiation should not exceed a value of 0.3 W/m^2, the value associated with the erythematous weighted maximum irradiation, which is equivalent to the tropical sun, called extreme by the World Health Organization (with the specification that it is valid only for the known acute effects) [2,8].

Following the evaluation of the risk of malignant diseases, especially those of the skin, it is not possible to establish some limits regarding the dose due to the lack of dose response data in humans [9]. The main factors that lead to the appearance of malignant transformations are of two types: biological factors (age, sex, skin phenotype, family history, moles) and environmental factors (mode of exposure to ultraviolet radiation) [2,10].

Aim and objectives

The main purpose of this study is to highlight the effects produced by ultraviolet radiation, through the prism of its use for diagnostic and therapeutic purposes in the field of dental medicine, but without neglecting the negative effects produced on the skin, the first defense barrier of the human body against harmful factors in the environment. At the same time, the connection between the damage to oral quality due to exposure to environmental

ultraviolet radiation and the state of knowledge in the field regarding the effectiveness of the use of ultraviolet radiation in the newest techniques in dentistry is analyzed.

MATERIAL AND METHODS

Six specialized databases were used for the original systematic study: PubMed, Science Direct, de Gruyter, Wiley Online Library, Springer, and Google Scholar. The databases were searched for research and analyzes that describe the involvement of ultraviolet radiation in the field of dentistry, but also their connection with malignant skin diseases. The search was focused on the six databases in English and later the bibliographic references of the research considered relevant. The selection criteria were based on the importance of using ultraviolet radiation for diagnostic and treatment purposes in the field of dentistry, and following the analysis of the studies considered relevant, a quantification and interpretation of the results was carried out.

Further, a questionnaire was proposed to evaluate the specialized knowledge among the specialists in the field of dentistry. The selected studies were evaluated by a scientific committee whose members come from the disciplines involved in the study, together with specialists, and the following steps were taken: 1) reducing the number of studies to design a simple and concise questionnaire, 2) making decisions definitive questions related to the development of the questionnaire, 3) establishing the questions so that the answers can be scored based on a Likert-type scale from 1 to 4.

RESULTS AND DISCUSSIONS

Ultraviolet radiation is one of the oldest methods used for sterilization/decontamination and is still successfully used to inactivate various microorganisms. In dentistry, ultraviolet radiation is used for both diagnostic and therapeutic purposes. Ultraviolet light is an invisible light, with few exceptions, the cases where fluorescence occurs, one of the properties for which it is used intensively in modern medicine, as can be observed in figure 1 [11].

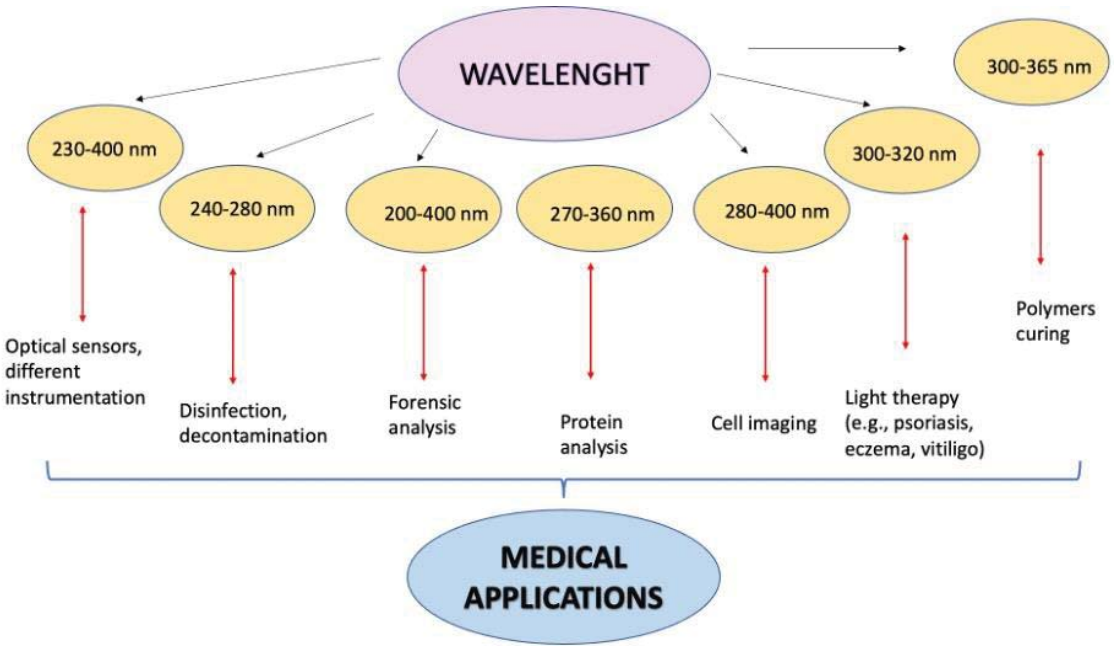

Figure 1. Ultraviolet radiation related to medical applications

At an initial search, in six different databases (PubMed, Science Direct, Wiley Online Library, de Gruyter, Springer and Google Scholar), after the keywords "ultraviolet radiation in dental medicine", the results were extremely varied, as can be seen in the figure below (figure 2).

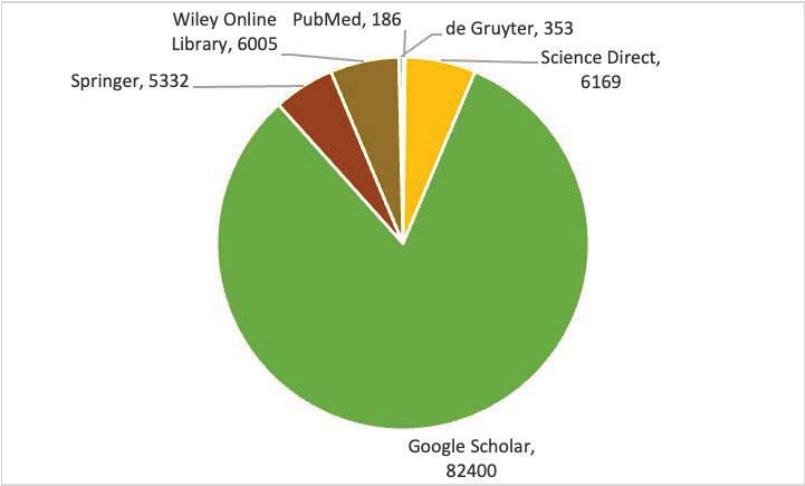

Figure 2. Ultraviolet radiation in dental medicine – results from databases

Several key searches were performed in the mentioned databases, and the results of the searches are presented in figure 3.

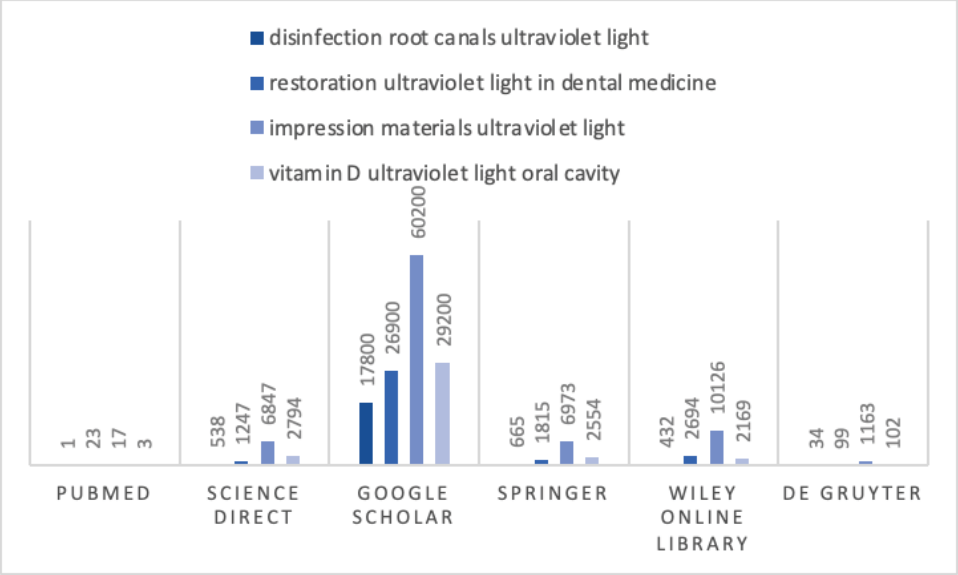

Figure 3. Ultraviolet radiation related to disinfection of root canals, restoration, impression materials and vitamin D – results from databases

Based on the literature study and following the analysis of the search results in the six databases, a questionnaire was proposed to be used by health specialists. The role of this questionnaire is to increase the knowledge related to the applicability of ultraviolet light in dental medicine, to deepen the knowledge related to the latest techniques that use ultraviolet light in dental medicine and to be aware of both the beneficial effects and the risks deriving from the use of ultraviolet light in the oral cavity.

Table 1. Questionnaire model for specialists in the field of dentistry

Questions	Responses/Observations
Are you concerned with the use of techniques that involve ultraviolet radiation in the diagnosis of dental conditions?	
Specify if you have in-depth knowledge about the use of ultraviolet radiation in the medical field	
How often do you use ultraviolet light in the specialized techniques you practice?	
Do you use ultraviolet radiation for root canal disinfection?	
Do you use ultraviolet radiation for restoration?	
Do you use ultraviolet radiation for impression materials?	
What do you know about the role of vitamin D production after exposure to ultraviolet radiation and the effects in the oral cavity?	
Describe the products you use most frequently that involve ultraviolet radiation	
Describe the products (which involve ultraviolet light) that present risks for specialized personnel	
What do you think about the use of ultraviolet radiation in combination with classic treatments against microbial agents in the oral cavity?	
Do you know if there is any connection between exposure to ultraviolet radiation and the occurrence of oral cancer?	

One of the frequent uses in dental technique is related to working with resins in the oral cavity. A series of composite resins have the property of emitting fluorescence in contact with ultraviolet light (optimal excitation length 385-395 nm), being divided into intensely fluorescent composite resins, moderately fluorescent composite resins and weakly fluorescent composite resins [12]. The application of ultraviolet light is a particularly useful technique that helps the specialized medical staff to evaluate the complete removal of this in each individual case. Data related to the fluorescent properties of composite resins, in the presence of ultraviolet light, are detailed and reliable. Therefore, following the development of technology in recent years, reliable tools have been developed that can be easily manipulated by dentists (e.g., flashlights with ultraviolet light emitting diodes) and more. Even forensic doctors can use these tools in special conditions, in which victims are identified by dental impressions, because currently amalgams are no longer used in dental procedures, but composite resins [13]. For example, it should be mentioned that resin brands emit fluorescence at certain varying wavelengths and at the same time, with intensities [14]. Therefore, the use of flashlight-type devices revealed that the most useful excitation wavelengths, for the detection of composite resin, are in the range of type A ultraviolet radiation (365 and 380 nm) [12,15]. Thus, restorations (for example those made of porcelain) and fillings (based on composite resin) can show different responses to the mentioned wavelengths, thus the use of both is recommended, especially in the forensic field [11].

Another application of ultraviolet light in dentistry is based on its disinfecting properties. In the case of using ultraviolet light (254 nm, 300 mJ/cm^2) as a disinfection technique on root canals, immediately after treatment with 5% sodium hypochlorite, it led to spectacular results regarding the eradication of *Enterococcus faecaliss* [16,17]. Therefore, the application of ultraviolet radiation to the root canals can be a successful complementary technique in combating harmful microorganisms found in the oral cavity.

And in the case of bacteria that produce tooth decay, ultraviolet light finds its applicability. These bacteria, following metabolic processes, generate porphyrins which, following ultraviolet light irradiation, emit a specific red fluorescence [11].

The impression materials are also sterilized with the help of ultraviolet light, with different results [18]. Specialized research has highlighted the effectiveness of using ultraviolet light, specifying that silicone-based impressions can be sterilized with ultraviolet light (sterilization period 20 minutes) [11,19].

Regarding the processes that take place in the skin following exposure to ultraviolet radiation, the mechanisms involved are multiple, some of them understood, some of them incompletely elucidated. What is known for sure is that exposure to ultraviolet radiation stimulates the natural production of vitamin D. Therefore, the beneficial effects exerted are closely related to this process, taking into account the fact that vitamin D has multiple roles in the body, among which regulates calcium metabolism, increases immunity, stimulates cell proliferation, keeps blood pressure within normal parameters, etc. [11]. As for the beneficial effects on the oral cavity, they are related to the beneficial action on calcium metabolism and the induction of cathelicidin (antimicrobial peptide) liable for fighting the bacteria responsible to produce dental caries [20]. Despite these known data, it is not yet known exactly whether the additional administration of vitamin D has a significant contribution in combating dental caries or in reducing the risk of their occurrence [21].

It is well known that UV radiation causes cell damage that can lead to malignant cell transformation. These radiations act directly on cellular molecules, causing DNA damage, through energy absorption, and induce the generation of intracellular reactive species. Instead, the use of ultraviolet radiation in an innovative cold plasma treatment device in the dental field has proven to be safe and a real success, taking into account the fact that no damage was recorded, and it was not proven to favor carcinogenesis [22]. Cold atmospheric pressure plasma is mainly used to promote re-osseointegration, decrease the risk of antimicrobial infections and contribute to wound healing. The long-term treatment of this method compared to the irradiation of cells was studied on an animal model and the results of the study indicated that the technique is safe, as no damage to the cells was recorded. In contrast, exposure of the cells to irradiation revealed non-invasive lesions and squamous cell carcinoma. Therefore, the repeated exposure of the cells to this treatment is well tolerated, being devoid of carcinogenic effects at the same time [22].

CONCLUSIONS

Studies reveal a connection between natural ultraviolet radiation (UV) and the occurrence of malignant processes. Oral cells are significantly more sensitive to ultraviolet radiation than skin cells. At the same time, the use of ultraviolet radiation in the dental field, both for diagnostic and therapeutic purposes, is devoid of significant adverse effects. The antimicrobial activity in the dental sphere of ultraviolet radiation has been proven to be pronounced, especially when they are used in combination with classic disinfection treatments. However, there is a need to deepen the mechanisms involved in the damage to oral cells by the two types of ultraviolet radiation of clinical interest, UV type B and UV type A, considering their origin (natural/synthetic), exposure time and the dose used.

REFERENCES

1. Lerche CM, Philipsen PA, Wulf HC. UVR: sun, lamps, pigmentation and vitamin D. Photochem Photobiol Sci 2017, 16, 291-301. doi: 10.1039/C6PP00277C
2. Brenner M, Hearing VJ. The protective role of melanin against UV damage in human skin. Photochem Photobiol. 2008, 84(3), 539-549. doi: 10.1111/j.1751-1097.2007.00226.x.

3. European Comission – Scientific Committee on Cosumer Products, opinion on Biological effects of ultraviolet radiation relevant to health with particular reference to sunbeds for cosmetic purposes. Available at https://ec.europa.eu/health/ph_risk/committees/04_sccp/docs/sccp_o_031b.pdf (Accessed on 3 February 2023)
4. Emri G, Paragh G, Tósaki Á, Janka E, Kollár S, Hegedűs C, Gellén E, Horkay I, Koncz G, Remenyik É. Ultraviolet radiation-mediated development of cutaneous melanoma: An update. J Photochem Photobiol B. 2018, 185, 169-175. doi: 10.1016/j.jphotobiol.2018.06.005.
5. United States Environmental Protection Agency – Health Effects of UV Radiation. Available at https://www.epa.gov/sunsafety/health-effects-uv-radiation (Accessed on 3 February 2023)
6. Le Clair MZ, Cockburn MG. Tanning bed use and melanoma: Establishing risk and improving prevention interventions. Prev Med Rep. 2016, 3, 139-44. doi: 10.1016/j.pmedr.2015.11.016.
7. Plitta-Michalak B, Stricker N, Pavez Loriè E, Chen I, Pollet M, Krutmann J, Volkmer B, Greinert R, Boukamp P, Rapp A. Development and characterisation of an irradiation device for biomedical studies covering the solar spectrum with individual regulated spectral bands. Photochem Photobiol Sci 2022, 21, 1701–1717. doi: 10.1007/s43630-022-00252-w
8. EN 60335-2-27:2013/A1:2020 - Household and similar electrical appliances - Safety - Part 2-27: Particular requirements for appliances for skin exposure to ultraviolet and infrared radiation. Available at https://standards.iteh.ai/catalog/standards/clc/d1399a3d-4b9d-466f-8140-5ee117bb40b0/en-60335-2-27-2013
9. Söderberg PG, Michael R, Merriam JC. Maximum acceptable dose of ultraviolet radiation: a safety limit for cataract. Acta Ophthalmol Scand. 2003, 81(2), 165-169. doi: 10.1034/j.1600-0420.2003.00033.x.
10. Davey MG, Miller N, McInerney NM. A Review of Epidemiology and Cancer Biology of Malignant Melanoma. Cureus. 2021, 13(5), e15087. doi: 10.7759/cureus.15087.
11. Panov V, Borisova-Papancheva T. Application of ultraviolet light (UV) in dental medicine. MedInform 2015, 2, 194-200. doi: 10.18044/MedInform.201522.194
12. Brokos I, Stavridakis M, Lagouvardos P, Krejci I. Fluorescence intensities of composite resins on photo images. Odontology. 2021, 109(3), 615-624. doi: 10.1007/s10266-020-00583-z.
13. Guzy G, Clayton MA. Detection of composite resin restorations using an ultraviolet light-emitting diode flashlight during forensic dental identification. Am J Forensic Med Pathol. 2013, 34(2), 86-89. doi: 10.1097/PAF.0b013e3182886f77.
14. Garrido TM, Hoshino LC, Hirata R, Sato F, Neto AM, Guidini VH, Terada RS. In vitro evaluation of composite resin fluorescence after natural aging. J Clin Exp Dent. 2020, 12(5), e461-e467. doi: 10.4317/jced.56535.
15. Albertini P, Tauro R, Barbara L. Albertini E, Lombardo L. Fluorescence-aided removal of orthodontic composites: an in vivo comparative study. Prog Orthod. 2022, 23, 16. doi:10.1186/s40510-022-00411-w.
16. Metzger Z, Better H, Abramovitz I. Immediate root canal disinfection with ultraviolet light: an ex vivo feasibility study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007, 104(3), 425-33. doi: 10.1016/j.tripleo.2007.03.027. PMID: 17709074.
17. Sohrabi K, Sooratgar A, Zolfagharnasab K, Kharazifard MJ, Afkhami F. Antibacterial Activity of Diode Laser and Sodium Hypochlorite in Enterococcus Faecalis-Contaminated Root Canals. Iran Endod J. 2016, 11(1), 8-12. doi: 10.7508/iej.2016.01.002.
18. Kotwal M, Singh VP, Mushtaq H, Ahmed R, Rai G, Kumar A. Disinfection of Impression Materials with Glutaraldehyde, Ultraviolet Radiation, and Autoclave: A Comparative Study. J Pharm Bioallied Sci. 2021, 13(Suppl 1), S289-S292. doi: 10.4103/jpbs.JPBS_755_20.
19. Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Cornejo-Ríos E, Tosco V, Monterubbianesi R, Mancino S, Eid A, Mancino D, Kharouf N, Haikel Y. Disinfection Procedures and Their Effect on the Microorganism Colonization of Dental Impression Materials: A Systematic Review and Meta-Analysis of In Vitro Studies. Bioengineering. 2022, 9(3), 123. doi:10.3390/bioengineering9030123
20. Khurshid Z, Naseem M, Yahya I Asiri F, Mali M, Sannam Khan R, Sahibzada HA, Zafar MS, Faraz Moin S, Khan E. Significance and Diagnostic Role of Antimicrobial Cathelicidins (LL-37) Peptides in Oral Health. Biomolecules. 2017, 7(4), 80. doi: 10.3390/biom7040080.

21. Grant WB. A review of the role of solar ultraviolet-B irradiance and vitamin D in reducing risk of dental caries. Dermatoendocrinol. 2011, 3(3), 193-198. doi: 10.4161/derm.3.3.15841.
22. Evert K, Kocher T, Schindler A, Müller M, Müller K, Pink C, Holtfreter B, Schmidt A, Dombrowski F, Schubert A, von Woedtke T, Rupf S, Calvisi DF, Bekeschus S, Jablonowski L. Repeated exposure of the oral mucosa over 12 months with cold plasma is not carcinogenic in mice. Sci Rep. 2021, 11(1), 20672. doi: 10.1038/s41598-021-99924-3.