• Brief Report •

Effect of open ultraviolet germicidal irradiation lamps on functionality of excimer lasers used in cornea surgery

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Abstract
● **We report on the impact of direct ultraviolet germicidal irradiation (UVGI) on reflective optics, used in the excimer laser system Allegretto Eye-Q. The aim of our work was to confirm our hypothesis based on long-rate observations of obtained anomalies in post-operative results that are attributed to degradation of reflective optics upon ultraviolet radiation. The presence of direct UVGI coupled with humidity in the operating environment caused merging anomalies and unwanted post-operative correction values. Ultraviolet-A radiation caused a similar effect on the reflective cover of the mirrors.**
● **KEYWORDS:** ultraviolet radiation; excimer lasers; post-operative anomalies; laser-assisted *in situ* keratomileusis; mirror degradation
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INTRODUCTION
Lamps emitting ultraviolet germicidal irradiation (UVGI) have been used as an effective method for air disinfection in hospital operating rooms since 1936[1]. Such lamps produce short-wavelength ultraviolet (UV) radiation, also known as ultraviolet-C (UV-C)[2]. Producing UV radiation (190-290 nm) of sufficient intensity demonstrates strong disinfection effect and prevents spread of certain infectious diseases by inactivating microbes *via* damaging their deoxyribonucleic acid (DNA)[3-5]. Therefore, low-pressure mercury (Hg) discharge lamps (254 nm) are commonly used as the most effective ones in sterilization of work facilities[6]. To increase the efficiency of air purification, shielded UV lamps using forced circulation of air by a fan, have been developed[7]. In this case the probability of unwanted chemical effects in surgical environments is reduced[1]. Nevertheless, lamps of open UV-C are still being used in air disinfection and such long-term exposure to UV can cause various negative effects such as UV degradation.

In polymers the long-term exposure to UV light activates oxidation of bonds forming carbonyl groups in the polymer chains. Such radiation breaks molecular bonds and leads to cracking, bleaching in dark opaque materials or yellowing of the surface[8]. In first surface mirrors (front-coated mirrors) very similar effects may occur[9]. In comparison with ordinary mirrors these types of mirrors have the reflecting surface placed on the front surface of the glass being more vulnerable and less protected from corrosion. The reflective coating is usually made of silver or aluminum[9]. Both metals are subjected to corrosion, also known as oxidation, which can be accelerated by UV light[10]. To prolong the specular reflectance of the mirrors, various adhesives and protective layers are deposited on the metallic layer and such technique also eliminates needless reflection from glass surface in back mirrors. Furthermore, it is used when working with various instruments requiring precision such as excimer lasers. The increasing use of Argon fluoride (ArF) excimer lasers (193 nm) in surgical procedures has produced various optical components and thin film coatings for this type of radiation[11-13]. For example, elements being responsible for tracking of a pupil's movement during refractive eye surgery by reflecting the infrared (IR) illumination to an IR camera, or mirrors deflecting the UV laser beam from a beam path to the surgical area. Since these elements are more sensitive to environmental changes due to its location, it may merge in an improper functionality of excimer laser systems. So far, little has been published on it and, therefore, the aim of this study was to confirm our hypothesis based on long-rate observations of obtained anomalies in post-operative results that are attributed to degradation of reflective optics upon UV radiation.

METHODS
We performed a post-operative analysis of patients treated by laser-assisted *in situ* keratomileusis (LASIK). Subjects were identified through an electronic WaveLight Oculyzer Patient Database. Informed consent was obtained from all subjects and the study was conducted in accordance to the Declaration of Helsinki.

For this study two WaveLight Allegretto Eye-Q excimer laser systems with ablation repetition frequency of 400 Hz were used to perform LASIK procedures[14].

For pre-operative and post-operative non-contact measurements and analysis of the anterior eye surface the WaveLight Oculyzer II diagnostic device was used.

Each laser system was located in a separate operating-room with different models of UVGI disinfecting lamps. For direct and shielded UV-C sources ОБН-150 (OBN-150) and UltraViol NBVE 110 NL lamp models (254 nm) were used, respectively. Both laser systems contained new identical and recently replaced non-defective reflective IR mirrors. These mirrors reflect the IR radiation from the cornea to the IR camera, thus allowing to track the position of the pupil.

A layer of sodium chloride solution (9 g/L of NaCl) was partially deposited on both IR mirrors of two systems and exposed to UV-C radiation. To compare effects of longer wavelengths on the mirror surface a black light source LAMP08TBL (315-400 nm) was used in the experiment.

A time dependent degradation of the mirror surface within the period of half a year was investigated upon both UV-C and ultraviolet-A (UV-A) radiation sources.

RESULTS AND DISCUSSION

Initially, surgeons using laser systems, pre-exposed to open UVGI sources, observed anomalies in measured curvatures of the post-operative anterior surface of the cornea. To explain such discrepancy, we assumed that the reflective mirrors could be affected by the open UVGI lamps. Indeed, both checked IR mirrors had clearly visible degradation signs (Figure 1).

For comparison, reflective mirrors in the laser system located in the operating room with shielded UVGI lamps had no visually observed degradation in its reflective surface. Moreover, after both mirrors used for reflection of IR illumination were replaced with new ones, no abnormal results after LASIK procedures were obtained throughout the period of observation.

To confirm our hypothesis, the previously explained experiment was conducted. Both IR mirrors were placed at its original positioning within the laser system and the left side of the mirrors was continuously poured with NaCl solution. Afterwards, the degree of mirror degradation (the corroded part of the mirror surface) was investigated and was shown in Figure 2.

Since continuous exposure to UV is more harmful to the optics than intermittent exposure[10], even mirrors applied to reflection of pulsed laser beam may degrade upon UV-C irradiation. This type of UV degradation upon impact of humidity, also known as oxidation, was previously investigated and published by Hernandez *et al*[9]. Meanwhile, similar consequences concerning the surface degradation were observed upon exposure to longer UV wavelengths (Figure 2). The mirror surface is significantly corroded in the area the droplet was

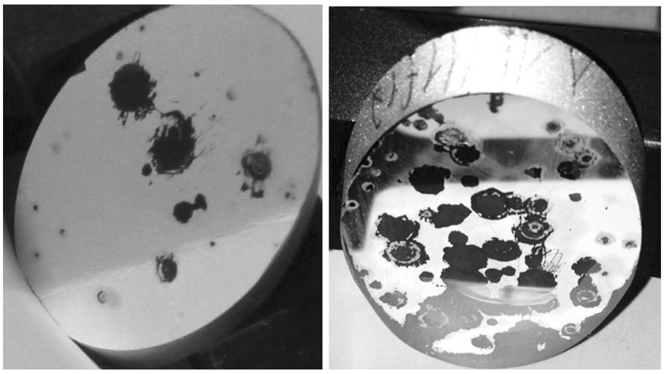

Figure 1 Degraded mirrors for reflection of IR illumination (eye tracking).

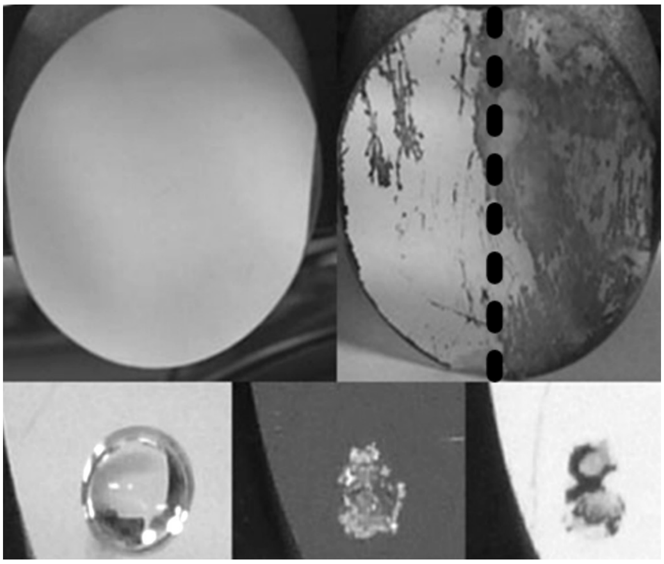

Figure 2 IR mirror degradation upon UV-C radiation From left to right, the new and the washed out after degradation surface. The dashed line corresponds to the boundary between the mirror area upon (left) and without (right) the NaCl solution. Below, IR mirror degradation upon UV-A radiation: a droplet of NaCl solution, a dried surface and a degraded mirror cover after being washed out.

left and dried, suggesting that the covering surface also can be effected by UV radiation of longer wavelengths[5,9,11,13].

The findings of this investigation showed that the reflectivity of the mirror surface is effected by the presence of humidity due to modification of the protective coating, regardless to other mechanisms as a simple contamination or sputtering erosion (enhanced radiation effects)[5,11,13,15]. The presence of humidity on both mirrors may be explained by its location in the vicinity of the ablation area. In this case, small droplets or spurts of NaCl solution may pass to the mirror surface occasionally during the LASIK procedures. It is also possible, that the mirror degradation is induced by the treatment beam (193 nm, <2 W, pulse energy <1.5 mJ). We assume, that the UV radiation is reflected from medical instruments used during the surgery process. Various pincers *etc*, made of metal alloys, can easily reflect the radiation to the eye-tracking mirror as they are merely used in the vicinity of the pupil during the ablation procedure. Our assumption seems to be valid due to a round shape (the shape of the treatment beam is also round) of the degradation area seen in Figure 1.

In conclusion, this study has shown, that the presence of direct UV germicidal irradiation coupled with humidity in the operating environment may cause merging anomalies and unwanted post-operative correction values. UVGI lamps and humidity may therefore serve as a key factor of enhanced mirror corrosion and disruption of the protective coating. Findings of this study may be useful to engineers and medical staff for preventing laser optics from being damaged.

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Conflicts of Interest: Belovickis J, None; **Kurylenka A,** None; **Murashko V,** None.

REFERENCES

1 Hart D. Sterilization of the air in the operating room by special bactericidal radiant energy: results of its use in extrapleural thoracoplasties. *J Thorac Surg* 1936;37(6):45-81.

2 Reed NG. The history of ultraviolet germicidal irradiation for air disinfection. *Public Health Reports* 2010;125(1):15-27.

3 Kanaan M, Ghaddar N, Ghali K. Localized air-conditioning with upper-room UVGI to reduce airborne bacteria cross-infection. *Building Simulation* 2015;9(1):63-74.

4 Jelden KC, Gibbs SG, Smith PW, Hewlett AL, Iwen PC, Schmid KK, Lowe JJ. Comparison of hospital room surface disinfection using a novel ultraviolet germicidal irradiation (UVGI) generator. *J Occup Environ Hyg* 2016;13(9):690-698.

5 Kanaan M, Ghaddar N, Ghali K, Araj G. Upper room UVGI effectiveness with dispersed pathogens at different droplet sizes in spaces conditioned by chilled ceiling and mixed displacement ventilation system. *Build Environ* 2015;87(1):117-128.

6 Pirnie M, Linden KG, Malley JP. Ultraviolet disinfection guidance manual for the final long term 2 enhanced surface water treatment rule. Washington, DC: National Service Center for Environmental Publications (NSCEP) 2006. Available at http://epa.gov/safewater/desinfection/lt2/compliance.html; Accessed on Jul 18,2016.

7 Eisner AD, Richmond-Bryant J, Hahn I, Drake-Richman ZE, Brixey LA, Wiener RW, Ellenson WD. Analysis of indoor air pollution trends and characterization of infiltration delay time using a cross-correlation method. *J Environ Monit* 2009;11(12):2201-2206.

8 Lapshin RV, Alekhin AP, Kirilenko AG, Odintsov SL, Krotkov VA. Vacuum ultraviolet smoothing of nanometer-scale asperities of Poly(methyl methacrylate) surface. *J Surf Investi-X-Ra* 2010;4(1):1-11.

9 Hernandez T, Morono A, Hodgson ER. Radiation enhanced degradation of aluminium mirrors for remote handling and diagnostics applications: effect of humidity. *Fusion Engineering and Design* 2003;69(1-4):177-182.

10 Coblentz WW, Stair R. Reflecting power of beryllium, chromium, and several other metals. *Bureau of Standards Journal of Research* 1929;2(2): 343-354.

11 Callahan GP, Flint BK. Characteristics of deep UV optics at 193nm and 157nm. *Mini-Symposium on Optics for the Deep UV* 1998;3578(1): 45- 53.

12 Delord C, Blaise A, Fernandez-Garcia A, Martinez-Arcos L, Sutter F, Reche-Navarro TJ. *Soiling and Degradation Analysis of Solar Mirrors*. Solarpaces 2015: International Conference on Concentrating Solar Power and Chemical Energy Systems 2016;1734(1):090001-1-090001-8.

13 Girard R, Delord C, Disdier A, Raccurt O. *Critical constraints responsible to solar glass mirror degradation*. International Conference on Concentrating Solar Power and Chemical Energy Systems, Solarpaces 2014 2015;69(1):1519-1528.

14 Boodman SG. Medical Mystery: Preparation for surgery revealed cause of deteriorating eyesight. Health & Science: The Washington post; 2011: Available at https://www.washingtonpost.com/national/health-science/medical-mystery-preparation-for-surgery-revealed-cause-of-deteriorating-eyesight/2011/11/26/gIQAwVLj4O_story.html; Accessed on July 18,2016.

15 Voitsenya VS, Bardamid AF, Bondarenko VN, Jacob W, Konovalov VG, Masuzaki S, Motojima O, Orlinskij DV, Poperenko VL, Ryzhkov IV, Sagara A, Shtan A, Solodovchenko SI, Vinnichenko MV. Some problems arising due to plasma-surface interaction for operation of the in-vessel mirrors in a fusion reactor. *J Nucl Mater* 2001;290(1):336-340.