A Groundbreaking Solution for Limited Penetration of 222 nm Far-UVC in Large Droplets: Innovative Design of a Modified Irradiator for Enhanced Airborne Pathogen Control in Dental Settings

Farshad Goharmanesh (MSc)[1], Abdolkarim Ghadimi-Moghadam (MD)[2], Masoud Haghani (PhD)[3], Seyed Ali Reza Mortazavi (MD)[4], Seyed Mohammad Javad Mortazavi (PhD)[1,5], Ghazal Mortazavi (DDS)[6]*

[1]Department of Medical Physics and Engineering, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Department of Pediatrics Infectious Diseases, Yasuj University of Medical Sciences, Yasuj, Iran
[3]Department of Radiology, School of Paramedical Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[4]MVLS College, The University of Glasgow, Glasgow, Scotland, UK
[5]Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC), Shiraz University of Medical Sciences, Shiraz, Iran
[6]Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author: Ghazal Mortazavi
Shiraz University of Medical Sciences, Shiraz, Iran
E-mail: qaz.mortazavi@gmail.com

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ABSTRACT

In the wake of the COVID-19 pandemic, maintaining hygienic dental practice environments has become imperative due to the risk of SARS-CoV-2 exposure to dentists and patients. A novel infection control system has been developed, combining far-UVC light with an infrared-based hot air blower, aimed at significantly reducing pathogen spread in dental settings. This groundbreaking system leverages the germicidal properties of 222 nm far-UVC light known for inactivating viruses on surfaces and within aerosols, while circumventing the limitations posed by droplet size and composition through the strategic use of a hot air chamber. The invention includes an integrated built-in air suction device at the dental chair's headrest for removing contaminated air, a circular floor-level suction system for enhanced air circulation, and a state-of-the-art 222 nm far-UVC lamp within established safety parameters. The hot air chamber's primary function is to decrease droplet size via evaporation, thus augmenting 222 nm far-UVC light penetration to effectively neutralize pathogens. A supporting blower system evenly distributes the hot air for consistent droplet exposure to far-UVC light, while a HEPA-based air purifier re-circulates purified air back into the clinic. This integrated system not only aims to provide a safer environment by minimizing airborne transmission of viruses but also stands as a vital evolution in infection control within the dental industry. Its implementation in dental practices could revolutionize standards of care and patient safety in the ongoing global effort to mitigate infectious healthcare risks.

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Keywords

Far-UVC; Infections; Airborne Diseases; SARS-CoV-2; COVID-19; Droplet

Introduction

Providing dental care is crucial, however, dentists are constantly at risk of being exposed to SARS-CoV-2. The elements that impact the delivery of dental care include the amount of virus exposure, frequency of interactions, duration of exposure, proximity to an infected individual, and the use of personal protective equipment [1]. Even dentists with good intentions of providing proper care to their patients may unknowingly contribute to the rapid and widespread transmission of the virus [2, 3]. Notable distinctions in the effectiveness of dental chair wrapping versus the use of purification devices for disinfecting the clinic is reported pre and post-COVID [4].

Far-UVC light (222 nm) has been investigated for its potential to inactivate various pathogens, including viruses, without causing harm to human tissues that traditional UVC light can [5-7]. However, its effectiveness can depend on factors such as the type of virus, the intensity and duration of exposure, and the medium through which the UVC light is transmitted. Regarding the inactivation of viruses in a large droplet, the effectiveness of 222 nm far-UVC would depend on the properties of the droplet, including its size, composition, and the location of viruses within it. Many people believe that far UVC can deactivate coronaviruses, but it is important to also consider whether far UVC can penetrate large droplets containing components like salivary proteins. Additionally, it is important to note that humidity has a strong impact on the effectiveness of far UVC in similar environmental conditions, as high humidity can prevent large droplets from evaporating quickly into droplet nuclei. This means that for far UVC to be effective, it must be considered in the context of humidity levels, temperature, ventilation air flows, light intensity, and air quality [8]. Given this consideration, in large droplets, viruses on the surface or very near the surface may be inactivated, but those deep inside might be protected due to the limited penetration of UVC light in a large droplet [8].

Our innovative system represents a technological breakthrough in dentistry, specifically tailored to address the critical need for effective infection control measures, particularly in the context of the COVID-19 pandemic. The proposed invention integrates far-UVC irradiation with an infrared-based hot air blower, forming a comprehensive system designed to minimize the spread of pathogens in dental settings. The primary objective of our invention is to revolutionize infection control in dentistry by harnessing the proven efficacy of far-UVC radiation in inactivating viruses, including coronaviruses. Through the integration of a modified system that combines far-UVC irradiation with a hot air blower, we aim to offer a practical and efficient solution for preventing the transmission of infectious agents within dental clinics.

Technical Presentation

The designed system comprises several integral components, including:

1. Built-in Air Suction Device

Integrated into the dental chair's headrest, this device facilitates the removal of potentially contaminated air in close proximity to the patient.

2. Circular Suction System

Positioned on the floor, this system ensures efficient air circulation within the dental setting, aiding in the removal of airborne particles.

3. Economic 222 nm Far-UVC Lamp

A crucial element emitting far-UVC irradiance, carefully calibrated to remain within the safety guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH) (Figure 1).

4. Infrared-Based Hot Air Chamber

An innovative feature designed to expedite

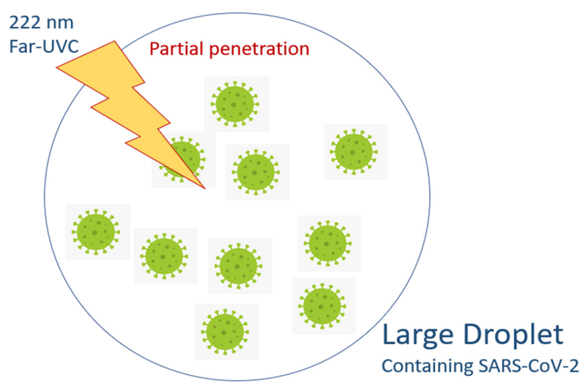

Figure 1: Limited penetration of 222-nm far-UVC in large droplets.

the evaporation of large droplets containing pathogens. The elevated temperature within the chamber accelerates droplet evaporation, reducing their size and allowing for deeper penetration of far-UVC radiation (Figure 2).

5. Blower

Facilitates the controlled dispersion of hot air, ensuring uniform exposure of droplets to the far-UVC irradiation.

6. HEPA-based Air Purifier

Further enhances air quality by removing particulate matter and ensuring the recirculated air is clean and free from potential contaminants.

Discussion

Our novel design addresses a key challenge associated with the limited penetration of 222 nm far-UVC by introducing a groundbreaking solution: the incorporation of a hot air chamber. This innovative feature plays a pivotal role in overcoming the obstacle of restricted penetration. By accelerating the evaporation of large droplets within the chamber, we effectively reduce their size. This reduction enhances the far-UVC radiation's ability to penetrate more deeply, ensuring comprehensive coverage and inactivation of viral particles, including those associated with highly contagious pathogens such as SARS-CoV-2. The strategic combination of far-UVC irradiation and the controlled evaporation of droplets within our system represents a significant advancement in technology, contributing to a more thorough and effective approach to airborne pathogen control in dental settings.

One standout feature of our invention is the hot air chamber, strategically incorporated to enable the rapid evaporation of large droplets containing pathogens. As these droplets are exposed to elevated temperatures within the chamber, they undergo swift evaporation, diminishing in size. This process enhances the effectiveness of far-UVC radiation, allowing it to fully penetrate and inactivate any remaining viral particles, including the highly transmissible SARS-CoV-2.

In our innovative design, every surface within the hot air labyrinth and maze UV irradiator channel is meticulously covered with specially engineered metallic antimicrobial surfaces, including copper-based coatings. This strategic incorporation of antimicrobial materials serves as an additional layer of defense against the persistence of pathogens. Copper, renowned for its potent antimicrobial properties, actively works to inhibit the growth and survival of bacteria and viruses on contact. By enveloping all surfaces with these advanced coatings, we establish a comprehensive and continuous

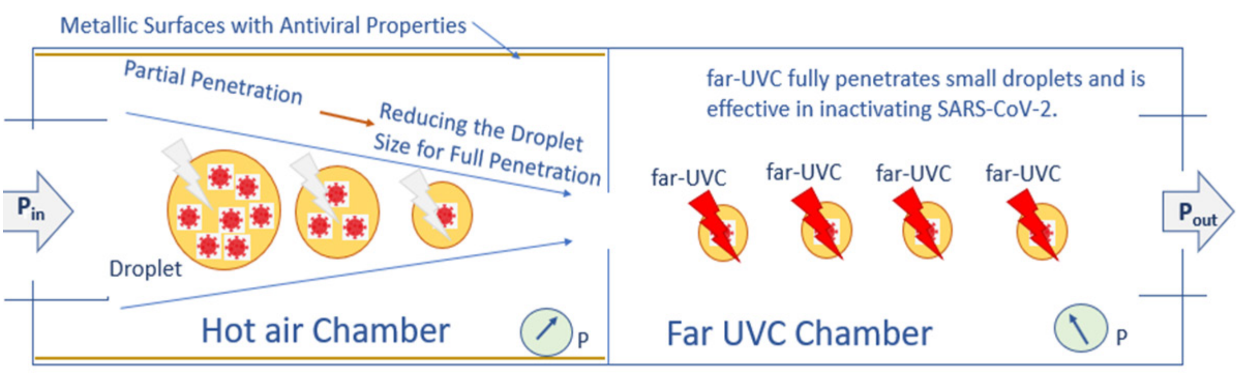

Figure 2: Heat within the infrared-based hot air chamber accelerates droplet evaporation, reduces their size and allows for deeper penetration of far-UVC radiation. A calibrated far-UVC irradiance system exposes the partially or fully evaporated droplets to 222 nm far-UVC.

antimicrobial shield throughout the intricate pathways of our system. This feature not only bolsters the overall efficacy of our design but also contributes to the long-term maintenance of a hygienic environment within dental settings, further ensuring the safety and well-being of both healthcare providers and patients.

Conclusion

The integration of far-UVC irradiation with an infrared-based hot air blower in our designed system represents a groundbreaking approach to airborne pathogen control in dental settings. Moreover, specially engineered metallic antimicrobial surfaces serve as an additional layer of defense against the persistence of pathogens. By combining these technologies, we provide a holistic solution that not only aligns with safety guidelines but also introduces an innovative mechanism for enhanced infection control. This advancement has the potential to significantly contribute to the resilience of dental facilities in the face of current and future airborne virus-related challenges.

Authors' Contribution

F. Goharmanesh, SMJ. Mortazavi, and Gh. Mortazavi conceived of the presented idea. Gh. Mortazavi developed the theory and performed the preliminary studies. F. Goharmanesh, SMJ. Mortazavi, and Gh. Mortazavi developed the design. All authors have contributed to the gathering of the writing/reviewing of the current manuscript and read, modified, and approved the final version of the manuscript.

Conflict of Interest

SMJ. Mortazavi, as the Editorial Board Member, was not involved in the peer-review and decision-making processes for this manuscript.

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