



Health risk assessment of inhalation exposure to dry fogging of hydrogen peroxide in a dental clinic during the COVID-19 pandemic

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Abstract

After the outbreak of COVID-19, many dental clinics use dry fogging of hydrogen peroxide (H₂O₂) to disinfect the air and surfaces. Inhalation of highly concentrated solutions of H₂O₂ may cause severe respiratory problems. This study aimed to estimate the health risk assessments of inhalation exposure to dry fogging of H₂O₂ in a dental clinic. This cross-sectional, descriptive-analytical study was performed to determine the inhalation exposure and health risk of 9 dental clinic staff with H₂O₂ in six rooms. Occupational exposure to H₂O₂ was assessed using the OSHA VI-6 method and a personal pump with the flow rate of 500 mL/min connected to the midget fritted-glass impinger containing 15 mL of TiOSO₄ collecting solution. The health effects of H₂O₂ exposure were assessed using a respiratory symptoms questionnaire. The health risk assessment of inhaled exposure to H₂O₂ was also performed using the method provided by the Singapore occupational health department. The mean respiratory exposure of clinic staff to H₂O₂ was ranged from 1.3 to 2.83 ppm for six rooms which was above the limits recommended by international organizations. Dyspnea (44.4%), cough (33.3%), and nasal burning (22.2%) were the most prevalent health problems. The results also showed a medium risk for endodontics and surgery, and lower risk for periodontics, restorative care, orthodontics, and prosthetics. The results of this study indicate that when using an automated hydrogen peroxide–vapor fogger, calculating the spraying time based on room volume and using the rooms after 30 min of fogging is very important and can greatly reduce the risk ranking.

Keywords Hydrogen peroxide · Dry fog · Inhalation exposure · Health risk assessment · Dental clinic · COVID-19

Introduction

In late 2019, the outbreak of COVID-19 caused by SARS-CoV2 in Wuhan, China was reported and spread rapidly around the world. SARS-CoV2 is a member of the β -corona family of viruses that affects pulmonary gas exchange and triggers cytokine storm. Severe inflammation, excessive coagulation, decreased lymphocyte count, and the increased neutrophil count are seen in the second week after the onset of the disease. Fever, dry cough, sneezing, shortness of breath, and respiratory distress are symptoms of COVID-19 (Noureen et al. 2022). Among the patients, men, the elderly, and those who have a variety of clinical problems such as cardiovascular disease and diabetic mellitus are at higher risk (Qureshi et al. 2021).

Preliminary studies have shown that the virus infects people through the inhalation route, directly/ indirectly (Peng et al. 2020). At direct exposure, the person exposes to the respiratory droplets released from the infected

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person. At indirect exposure, the person contacts to the infected surfaces (Barbato et al. 2020).

Due to their small size, respiratory droplets can remain suspended in the air for a long time. To prevent the transmission of the virus, it is necessary to disinfect the indoor air and surfaces. Air and surface disinfection systems were widely used in the COVID-19 pandemic. These systems disinfect the environment by spraying or fumigating disinfectants into the air (Raeiszadeh & Adeli 2020). Many public places such as restaurants, hotels, airports, stores, and hospitals have used these systems to control COVID-19 (Kimball et al. 2014).

Dry fogging is one of the methods that use compressed air for atomizing the disinfectant liquid into the air. The generated very small droplets can remain suspended in the indoor atmosphere for a long time, causing a higher disinfection rate (Bhandare & Goodridge 2021, Krishnan et al. 2012). Dry fogging with H_2O_2 has been used in various sectors including laboratories, biotech food production, and healthcare in recent years (Krishnan et al. 2012; Mørretrø et al. 2019). However, the outbreak of the novel coronavirus sparked the need for this technology to be used in many other public facilities, such as airports, train stations, hospitals, and malls (Kaklauskas et al. 2021). Because the ultrafine droplet of the dry fog remains in the air for hours, there is a possibility of respiratory exposure to H_2O_2 . Exposure to lower concentrations of H_2O_2 leads to coughing and transient dyspnea, while severe irritation, inflammation of mucous membranes, coughing and dyspnea appear at higher levels. Shock, coma, convulsions, and pulmonary edema may occur up to 24–72 h post-exposure (Advenier & de la Grandmaison 2018, Watt et al. 2004). Chronic exposure to lower levels of H_2O_2 in the workplace may result in chronic disorders such as chronic bronchitis, fibrosis, and lung cancer (Rahimi 2021).

Due to the patient's open oral cavity, instruments contact with saliva, blood, and other body fluids, many dental clinics use dry fogging to disinfect the air and surfaces (Manea et al. 2021; Miglani et al. 2020, Sher & Mulder 2020). Given the adverse effects of H_2O_2 on health care workers, assessing the health risk of respiratory exposure to H_2O_2 in the COVID-19 pandemic is essential. Health risk assessment as a monitoring tool is used to estimate the probability of adverse effects on the health of a group of people over a time (Atamaleki et al. 2021; Behrooz et al. 2021). To our knowledge, no study has been performed to evaluate the health effects of respiratory exposure to H_2O_2 emitted by dry fog in the workplaces. Accordingly, the present study was conducted to assess the respiratory exposure of dental clinic staff to H_2O_2 . Moreover, the health risk of respiratory exposure and the control strategies are estimated.

Materials and methods

Study information

This cross-sectional, descriptive-analytical study was performed in one of the dental clinics in Tehran, Iran. The clinic has 9 staff members working in 7 rooms of endodontics, periodontics, orthodontics, prosthetics, restorative care, and surgery.

The air and surface of rooms were disinfected using the automated hydrogen peroxide vapor fogger (Nocospray: Oxypharm, France). Disinfection was performed before each patient's visit. For this purpose, the vapor fogger is turned on for 4 min in an empty, enclosed room. The clinic does not have a heating, ventilation, and air conditioning (HVAC) system. The cooling system was also turned off because the study was conducted in the cold season. For disinfection to occur, it is recommended a minimum contact time of 30 min which was not considered due to a large number of patients.

Sample collection and analysis

To determine the clinic staff's exposure to H_2O_2 , personal air sampling was performed after the dental clinic staff entered the room. Since the sampling period was 30 min, air sampling was performed at 0 to 30, 30 to 60, 60 to 90, and 90 to 120 min. The OSHA VI-6 method was used to measure H_2O_2 concentrations in the rooms (OSHA 1978). Samples were collected from the respiratory area of the clinic staff by drawing air through a midget fritted-glass impinger containing 15 mL of $TiOSO_4$ collecting solution. A blank sample was also considered for each room. Sampling pumps were calibrated at approximately 500 mL/min before and after sampling with a digital calibrator. The H_2O_2 concentration of the sample is determined by the UV-vis spectrophotometer (Agilent, USA) set at 410 nm (Moradpour et al. 2021; OSHA 1978).

Determination of respiratory complaints

The respiratory symptoms questionnaire provided by the American Thoracic Society (ATS) was used to assess the health effects of H_2O_2 exposure (Jalali et al. 2021). The ATS questionnaire is an 8-item query about the respiratory status (coughing, wheezing, dyspnea, and chest compression), nasal, and eye burning. The two items of exercise and walking were not considered in the present study. The validity and reliability of the questionnaire have been investigated in previous studies (Cronbach's $\alpha = 0.86$).

(Cassidy et al. 2015). Data were collected through face-to-face interviews involving clinic staff.

Health risk assessment

Semi-quantitative health risk assessment related to H₂O₂ was performed according to the method provided by the Singapore Occupational Health Department (ministry of manpower 2005). The risk levels were calculated based on the hazard ratings (HR) and exposure ratings (ER), as shown in Eq. (1):

$$\text{Risk Rate} = \sqrt{HR \times ER} \quad (1)$$

The HR is assigned based on the carcinogenicity classifications established by the American Conference of Governmental Industrial Hygienists (ACGIH). ACGIH has indicated that H₂O₂ is a confirmed animal carcinogen with unknown relevance to human carcinogenicity (A3) (ACGIH 2021).

The ER is based on the ratio of the exposure level (E) to permissible exposure limit (PEL) or occupational exposure limit (OEL). The *E* was calculated using Eq. (2):

$$E = \frac{M \cdot D \cdot F}{W} \quad (2)$$

where *E* is the rate of weekly exposure in mg/m³ or ppm, *F* is the frequency of exposure per week, *M* is the rate of exposure in mg/m³ or ppm, *D* is the average duration of each exposure in terms of hours, and *W* is average working hours per week.

Table 1 Risk ranking

Risk level	Risk rank
1–1.7	Little
1.7–2.8	Low
2.8–3.5	Medium
3.5–4.5	High
4.5–5	Very high

Table 2 The occupational exposure (ppm) at different fogging times in clinic rooms

Clinic room	Number of dental unit	The volume of the room (m ³)	Time (in)				Mean (SD)	Median
			0–30	30–60	60–90	90–120		
Periodontics	2	60	3.48	1.29	0.44	ND*	1.3 (1.55)	0.865
Restorative care	2	55	3.62	1.33	0.52	ND	1.37 (1.6)	0.925
Orthodontics	2	55	3.71	1.45	0.6	ND	1.44 (1.63)	1.025
Prosthetics	1	35	5.35	2.02	0.78	ND	2.04 (2.36)	1.4
Endodontics	1	30	7.11	2.81	1.1	0.31	2.83 (3.04)	1.455
Surgery	1	30	6.72	2.49	0.88	ND	2.52 (2.98)	1.685

*Not detection.

According to the ACGIH, the occupational exposure limit for H₂O₂ is 1 ppm. For unusual work shifts, the OEL was adjusted with Eq. (3) (Verma 2000):

$$RF = \frac{40}{hr} \times \frac{168 - hr}{128} \quad (3)$$

where *RF* is the weekly reduction factor, and *hr* is the number of hours worked in 1 week.

The risk of occupational exposure to H₂O₂ was ranked using the risk level (Table 1).

Statistical analysis

Statistical analyses were performed using SPSS Version 16. All continuous data are presented as the mean ± standard deviation (SD) and median. Categorical data are presented as numbers and percentages.

Results and discussion

The occupational exposure to H₂O₂ in the dental clinic at different times after fogging is shown in Table 2. The time average concentration of H₂O₂ was in the range of 1.3 to 2.83 ppm for six rooms, which was above the exposure limit provided by the OSHA, NIOSH, ACGIH, and Iran's national occupational exposure limit (1 ppm) (ACGIH 2021). The results showed that the highest mean individual exposure was related to endodontics (2.83 ppm) and then surgery (2.52 ppm). The lowest mean occupational exposure was also determined for periodontics (1.3 ppm).

The differences observed in the results of different rooms can be due to differences in room volume. The endodontics and surgery rooms have a volume equal to half of the periodontics, which resulted in a twice exposure. According to the manufacturer's instructions, the spraying time should be calculated based on the volume of the room (3.6 s/m³) (Dorobanțu et al. 2015). Given this guide, spraying time is calculated to be 3.6 min for periodontics (60 m³) and 1.8 min for endodontics and surgery (30 m³). However, these calculations have not been

Table 3 Health problems associated with exposure to H₂O₂ in dental clinic

Clinic rooms	Health problems					
	Cough	Wheezing	Dyspnea	Chest compression	Nasal burning	Burning eyes
Periodontics	-	-	-	-	-	-
Restorative care	-	-	*	-	-	-
Orthodontics	-	-	-	-	-	-
Prosthetics	*	-	*	-	-	-
Endodontics	*	-	*	*	*	-
Surgery	*	-	*	-	*	-
<i>N</i> (%)	3 (33.3)	0 (0)	4 (44.4)	1 (11.1)	2 (22.2)	0 (0)

Table 4 Results of risk assessment of occupational exposure to H₂O₂ in dental clinics

Clinic rooms	E	ER	HR	Risk level	Risk rank
Periodontics	1.22	1.56	3	2.16	Low
Restorative care	1.28	1.64	3	2.22	Low
Orthodontics	1.35	1.73	3	2.28	Low
Prosthetics	1.91	2.45	3	2.71	Low
Endodontics	2.65	3.4	3	3.19	Medium
Surgery	2.36	3.02	3	3.01	Medium

Table 5 Results of risk assessment to H₂O₂ assuming no exposure in the first 30 min after fogging

Clinic rooms	E	ER	HR	Risk level	Risk rank
Periodontics	0.4	0.51	3	1.24	Negligible
Restorative care	0.43	0.55	3	1.28	Negligible
Orthodontics	0.48	0.62	3	1.36	Negligible
Prosthetics	0.66	0.85	3	1.6	Negligible
Endodontics	0.99	1.27	3	1.95	Low
Surgery	0.79	1.01	3	1.74	Low

performed, and the spraying time was considered 4 min for all the rooms. The lack of calculation for spraying time has caused the clinic staff to be exposed to the high concentration of H₂O₂. Fu et al. reported that the mean respiratory exposure of hospital staff with H₂O₂ was 1.3 ± 0.4 ppm with a maximum reading of 4.5 ppm in a 50-m³ room in St. George's Hospital, London (Fu et al. 2012). The results of this study are in line with the results of the present study.

The health problems associated with exposure to H₂O₂ are presented in Table 3. Surveying about the health problems due to the exposure showed that dyspnea (44.4%), cough (33.3%), and nasal burning (22.2%) had the highest prevalence. Also, the problems were more common in endodontics and surgery rooms that had more H₂O₂ than others (7, 7, and 3 symptoms for endodontics, surgery, and others, respectively). Human studies have also shown that respiratory exposure to H₂O₂ stimulates the nose and lungs. Yang and Liu found that exposure to highly concentrated H₂O₂ in a short term caused chest tightness, cough, general malaise, and piercing pain in the throat, (Yang & Liu 2021). Watt et al. found that inhalation of highly concentrated solutions of H₂O₂ can cause severe irritation and inflammation of mucous membranes, with coughing and dyspnea (Watt et al. 2004). ACGIH has reported that exposure to hydrogen peroxide stimulates the upper respiratory tract (ACGIH 2021). The results of this study also showed coughing, dyspnea, and nasal burning are common in the clinic staff, which are symptoms associated with upper respiratory tract irritation.

The results of the health risk assessment are presented in Table 4. In terms of carcinogenicity, H₂O₂ is classified in group A3 in the ACGIH classification. Therefore, according to the method provided by the Singapore Occupational Health Department, HR for H₂O₂ is 3. The calculated ER based on 8 h of work per day and 6 days per week was compared with the adjusted permissible limit of H₂O₂ (0.78). The results showed the range of risk levels in the clinic staff was 2.16 to 3.19. The highest risk level was found in endodontics (3.19). The lowest risk level belonged to the periodontics (2.16). The results of risk ranking showed a medium risk for endodontics and surgery and low risk for periodontics, restorative care, orthodontics, and prosthetics (Table 3). To our knowledge, it has been found that no study has been performed to evaluate the risk of respiratory exposure to H₂O₂ in dental clinics. Hong et al. determined the health risk of exposure to VOCs in dental clinics. Unlike the carcinogenic compounds, methylene methacrylate (2.8 ppm) and acetone (0.176 ppm), as non-carcinogenic ones indicated higher risks for human health (Hong et al. 2015).

Given that HR is 3 for all the rooms, the factor influencing the risk level is ER. Table 2 shows the maximum exposure that occurs in the first 30 min (3.48 to 7.11 ppm). According to the manufacturer's instructions and fogging disinfection guide, the room can be used after 30 min after fogging. In such circumstances, the estimated risk changes as shown in Table 5. The results show that if the clinic staff does not have exposure for the first 30 min, the risk ranking will change to lower rank.

One of the limitations of this work is conducting the study in only one clinic. It is expected that conducting studies in more clinics with different characteristics (HVAC, volume, exposure time, etc.) will help to better understand the personnel exposure.

Conclusion

The results of this study indicate that the dental clinic staff's exposure to H₂O₂ was higher than that recommended by international organizations and leads to the problems in respiratory tracts. Although the risk ranking in this study was medium and low, following the manufacturer's instructions and fogging disinfection guide, such as calculating the spraying time based on the room volume and using the room after 30 min of fogging, can greatly reduce the risk ranking.

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Data availability All the data generated or analyzed during this study are included in this published article.

Declarations

Ethical approval The present study was approved by the Ethics Committee of the Shahid Beheshti University of Medical Sciences through the ethical code: IR.SBMU.RETECH.REC.1399.800.

Consent to participate Not applicable.

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Competing interests The authors declare no competing interests.

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