

Indoor air quality in wards of dental school clinic: Variations of VOCs, CO₂ and airborne particle levels

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ABSTRACT

Introduction: The indoor environment of dental clinics may endanger dental patients and personnel and due to a great variety of air pollutants throughout the usual dental operation. The purpose of the present cross-sectional study was the evaluation of Indoor Air Quality (IAQ) and factors affecting it in a dentistry faculty of Arak University of Medical Sciences.

Material and methods: The IAQ of five dental active wards and the patient waiting room was evaluated. The concentrations of Total Volatile Organic Compounds (TVOC), CO₂, particulate matter, and bioaerosols were measured.

Results: The TVOCs concentration in sampling locations ranged between 817 to 3670 µg/m³ during dental work and exceeded the Leadership in Energy and Environmental Design (LEED) guideline in all sampling locations. The highest values of Particulate Matter (PM) for PM₁₀, PM_{2.5}, and PM₁ were observed in the periodontics ward, while the lowest values were observed in the endodontics ward. The PM_{2.5} concentrations exceeded the WHO limit in periodontics and pediatric wards. TVOC levels had a significant positive correlation with temperature ($r=0.374$, $p<0.01$) and RH ($r=0.265$, $p<0.05$). The predominant bacterial genus of the patient waiting area was Bacillus (36%), while the dominant bacterial genus of the other sampling site was Micrococcus spp. Penicillium (35.5%) and Cladosporium (28%) were the predominant fungi detected.

Conclusion: Controlling of airborne particles is to be standardized by the infection control actions of dental clinics and improved ventilation capacity in the air conditioning system was suggested for reducing VOCs and PM concentrations.

Introduction

In recent decades, Indoor Air Quality (IAQ) of health care settings has received growing attention from the researchers, and

governments for improving the health, and comfort of patients and health care workers [1]. IAQ in dental settings is of great importance for dentists, patients, and associated personnel whose health are endangered by infectious

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microbial aerosols and chemical compounds, and other pollutants [2]. In dental treatment, susceptibility to infected persons and chemical materials could be inevitable. The oral cavity is the main reservoir of infectious bacteria with over 350 different kinds [3]. Dental treatment procedures that use low and high-speed drilling and polishing released microbial aerosols and dental materials into the environment air. Microbial aerosols derived from saliva, blood, gum secretion, dental plaque, and nasal and throat secretion when is used ultrasonic scaler together with water spray. Aerosolized water droplets diffused from hand-pieces can also be contaminated with microbial biofilm existing in dental waterlines and reservoirs. Aerosol composition is different from case to case, depending on the site and the variety of treatment procedures in the oral cavity [4]. The effects of chronic exposure to airborne particles in dental offices contribute to the risk of development of respiratory cardiovascular diseases, chronic bronchitis reduced, lung function, and even premature death due to respiratory complications [5]. The main transmission route involves inhalation of pathogenic particles that stay suspended in air, settle on surfaces and are re aspirated. Non-living aerosols may release from acrylic, metal, mineral, polymers, and other compounds throughout dental operations and activities. The human health effects of Particulate Matter (PM) are directly related to their size and compositions [2]. PM comprises a great variety of species that differ in chemical composition, number, size (or diameter), surface area, and shape. These characteristics, especially surface area and size, define the expanse and position of deposition in the respiratory tract [6]. On the other hand, many chemical compounds containing resins and solvents are used in dental treatment works, even in regular dental treatment procedures, which could release nitrous oxide, mercury vapor, and Volatile Organic Compounds (VOCs) contaminants in

the atmosphere of dental clinics. Depending on dental works, particular VOCs are emitted in dental clinics, including methanol, methyl-methacrylate (MMA), isobutyl-methacrylate, and cyanoacrylate [7]. The source of VOCs in dental offices contributes to the production of bridges, crowns, acrylic dentures, and framework [7]. Other causes for the emission of VOCs can be chemical sterilization approaches in which well-known compounds, including glutraldehyde, alcohol, and ethylene oxide are used. Acute exposure to such VOCs can cause serious health effects, such as irritation of the eyes, nose, and throat, headaches, dizziness, and nausea. The risk of pulmonary illness, dermatological disease, and allergies may be increased by chronic exposure to such pollutants [5- 9]. Above all, high IAQ can defend dental patients and personnel against dangerous airborne substances existing in dental environments. Susceptibility to such substances is considerably more powerful in dental settings compared to other settings, necessitating a high IAQ. The current investigation was aimed at assessing the indoor air quality of different wards in the dentistry faculty of Arak University of medical sciences concerning microbial aerosols, TVOCs, PM, and CO₂ concentration to recognize potential sources and associations between particular dental actions and pollution levels.

Materials and methods

Sampling sites

This survey was conducted in the dental school clinic of Arak University of Medical Sciences, Arak, Iran. Air sampling and measurements were carried out in six separate active departments of the clinic, such as pediatric dentistry (PED), periodontics (PER), endodontics (ENDO), prosthesis (PRO), restorative dentistry (RES), and patient waiting room (PWR). Natural ventilation is used for these wards and central air conditioners (HVAC) are employed for heating and cooling.

The area of PED, PER, ENDO, PRO, and RES were 50 m², 50 m², 55 m², 90 m², 70 m² and 100 m² respectively. The windows were shut during sampling time. From each ward, two active dental chair units were randomly picked and air samples were collected at the distance of 2 m during the procedure treatment. This study was performed for six months from December 2018 to June 2019. IAQ parameters of sampling locations were measured for 6 h (10 am to 4 pm) per workday. The sample size for each sampling site was five.

The assessed parameters of air quality included airborne bacteria and fungi, three size fractions PM (PM₁₀, PM_{2.5}, and PM₁), Total Volatile Organic Compounds (TVOCs), CO₂, temperature, and relative humidity. Bacterial and fungal load were evaluated via Andersen one-stage impactors (N6; Andersen Samplers, Atlanta, Georgia) contained 20 ml TSA (tryptic soy agar) culture media for bacteria and MEA (malt extract agar) for fungi at an airflow rate of 28.3 L/min for 5 min. Duplicate samples were incubated at 35°C for 2-3 days for bacteria, and 25°C (room temperature) for 3-5 days, respectively. The number of colony-forming units per volume of air (CFU/m³) was calculated using the positive hole conversion table and sampled air volume. Total bacterial colonies were biochemically identified. The fungal genera were identified by macro-microscopic observation and morphological analysis [8]. The portable aerosol spectrometer (DustTruk Aerosol Monitor, TSI 8520) was employed for measuring PM₁, PM_{2.5}, and PM₁₀. A photoionization detector (PID, First multi-gas/PID detector Firstcheck) was also used to measure TVOC. During sampling, environmental parameters including temperature (°C) and relative humidity (RH %) were also determined using a digital Psychrometer (Kimo instrument, France). During the sampling period, all samples were collected 1.5 m above floor level. The estimation of the number of people in each ward was done based on the logbook records.

Statistical analysis

The SPSS 20.0 and Kolmogorov-Smirnov trial were used to conduct data analysis and normality was applied upon the usage of parametric and non-parametric analyses. Minimum, maximum, average, and standard deviation values were obtained to describe the indoor concentrations of pollutants. A comparison was made between the mean values of parameters among different wards using the Kruskal-Wallis trial. Also, the relationships between indoor air quality (IAQ) parameters were surveyed using the non-parametric Spearman's rank correlation approach. P values of less than 0.05 were defined for statistical significance.

Results and discussion

The mean and standard deviation of indoor air parameters from the six locations of the dental office are displayed in Table 1. The mean values of CO₂ concentration in sampling wards ranged from 775 ppm to 1180 ppm with the minimum value in PER and the maximum value in PED and exceeded the recommended limit (1,000 ppm) of the ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) for indoor environments [9]. The difference between the mean concentrations of CO₂ in the sampling wards was statistically significant (p<0.001). The RH and temperature variations in the sampling location were statistically significant (p<0.05). The PWA (background level) and PER recorded the highest mean temperature (25.2±1.3) and RH (42.4±2.3) during the measurement, respectively. The mean TVOCs concentrations in all sampling departments during working hours were above the Leadership in Energy and Environmental Design (LEED) recommended limit of 500 µg/m³ for the indoor air environment [10] (Table 1). The highest mean level occurred in the PRO (2737±936 µg/m³), while the minimum level was found in the PWR. The

mean TVOCs level in six sampling wards was statistically significant ($p < 0.005$). The highest values of PM_{10} , $PM_{2.5}$ and PM_1 were observed in PER, while minimum values were observed in the Endo (Table 1). According to the Kruskal-Wallis trial, no significant variations were observed in PM (PM_{10} , $PM_{2.5}$, and PM_1) concentrations between different sampling wards ($P = 0.406$). The maximum

value of PM_{10} concentration was $119 \mu\text{g}/\text{m}^3$, while that for $PM_{2.5}$ and PM_1 were $59 \mu\text{g}/\text{m}^3$ and $47 \mu\text{g}/\text{m}^3$, respectively. However, none of the concentrations of PM_{10} values exceeded the limit of $50 \mu\text{g}/\text{m}^3$ recommended by World Health Organization (WHO) [11]. The $PM_{2.5}$ concentrations exceeded the WHO limit of $25 \mu\text{g}/\text{m}^3$ in two sampling wards (PER and PED).

Table 1. Mean (SD) concentrations of air quality variables in the different sampling departments of the dental school clinic (n=180)

	(n=30)	(n=30)	(n=30)	(n=36)	(n=30)	Ground level (n=30)	limit
TVOCs, $\mu\text{g}/\text{m}^3$	1998 (439)	1840 (404)	2370 (759)	2243 (649)	2737 (936)	1300 (283)	^a 500
CO ₂ , ppm	775 (56)	952 (85)	790 (63)	1180 (92)	650 (48)	935 (89)	^b 1000
PM ₁ , $\mu\text{g}/\text{m}^3$	25 (7)	23 (6)	19 (5)	24 (7)	19 (6)	16 (4)	-
PM _{2.5} , $\mu\text{g}/\text{m}^3$	28 (8)	24 (7)	20 (5)	27 (9)	20 (7)	10 (5)	^c 25
PM ₁₀ , $\mu\text{g}/\text{m}^3$	48 (16)	30 (14)	22 (11)	46 (13)	22 (9)	19 (6)	^c 50
Bacteria, CFU/m ³	338	248	153	332	203	118	^d 500
Fungi, CFU/m ³	198	125	67	82	46	28	-
T °C	24.8 (0.8)	25.4 (1.1)	23.7 (2.1)	22.8 (0.6)	24.2 (1.4)	25.2 (1.3)	20-24
RH %	42.4 (2.3)	34.7 (3.1)	36.5 (1.9)	31.8 (1.4)	30.5 (2.9)	41.2 (1.7)	30-60

PER: periodontics department, RES: restorative department, ENDO: endodontics department, PED: pediatric department, PRO: prosthesis department, T: temperature, RH: relative humidity

^a USGBC, LEED v4. Building Design and Construction Guide [10]

^b ASHRAE, Standard 62.1-2016 for the Ventilation for Acceptable Indoor Air Quality [9]

^c World Health Organization (WHO) [11]

TVOCs were positively correlated with temperature significantly ($r=0.374$, $p<0.01$) and RH ($r=0.265$, $p<0.05$) (Table 2). Also, airborne bacteria were positively correlated with $PM_{2.5}$ ($r=0.301$, $p<0.05$) and PM_{10} ($r=0.243$, $p<0.05$). However, airborne fungi had significant positive correlation with CO_2 ($r=0.429$, $p<0.05$), temperature ($r=0.345$, $p<0.05$) and RH ($r=0.224$, $p<0.05$).

Table 2. Spearman rank correlation coefficients for indoor air quality parameters

	TVOCs	PM_{10}	$PM_{2.5}$	PM_1	CO_2	T	RH	Bacteria	Fungi
TVOCs	1								
PM_{10}	0.065	1							
$PM_{2.5}$	0.078	0.927**	1						
PM_1	0.102	0.876**	0.904**	1					
CO_2	0.016	0.023	0.017	0.011	1				
T	0.374**	0.011	0.006	0.003	-0.056	1			
RH	0.265*	0.017	0.008	0.004	-0.223	-0.305*	1		
Bacteria	0.033	0.218	0.301*	0.243*	0.147	-0.153	0.132	1	
Fungi	0.021	0.114	0.156	0.189	0.429*	0.345*	0.224*	0.109	1

T: temperature, RH: relative humidity

The results revealed that all the recognized bacterial genera in the present survey were gram-positive (Table 3). The dominant bacterial genera in sampling sites were *Micrococcus* (37.6%), *Bacillus* (24.5%), *Staphylococcus* (21.3%), and *Streptococcus* (16.6%). The predominant bacterial genus

of the PWA was *Bacillus* (36% of the total detected bacteria), while the dominant bacterial genus of the other sampling site was *Micrococcus spp.* Based on the findings of our investigation, the dominant fungal genera were *Penicillium* (35.5%), *Cladosporium* (28%), and *Aspergillus* (13.5%) (Table 3).

Table 3. Contributions of Bacterial and fungal genera in the six dental wards

	Frequency (%)					
	PED	PER	ENDO	PRO	RES	PWA
Bacteria genus						
<i>Micrococcus luteus</i>	18	10	14	ND	20	ND
<i>Micrococcus roseus</i>	10	6	4	8	ND	ND
<i>Micrococcus spp</i>	10	23	16	35	17	34
<i>Bacillus</i>	28	13	23	16	31	36
<i>Streptococcus spp</i>	14	11	28	21	25	ND
<i>Staphylococcus aureus</i>	5	8	3	1	ND	6
<i>Staphylococcus epidermidis</i>	9	13	12	7	7	ND
<i>Staphylococcus saprophyticus</i>	6	16	ND	12	ND	22
Fungi genus						
<i>Penicillium</i>	41	32	26	33	39	42
<i>Cladosporium</i>	16	21	40	30	23	31
<i>Aspergillus</i>	19	22	ND	12	28	ND
<i>Rhizopus</i>	9	14	16	ND	6	7
<i>Alternaria</i>	2	5	ND	22	ND	14
Others	13	6	18	13	6	6

PER: periodontics department, RES: restorative department, ENDO: endodontics department, PED: pediatric department, PRO: prosthesis department

Indoor air pollution of dental offices with volatile organic compounds (VOCs), different organic and inorganic chemicals, fine particulates, and airborne microorganisms can affect the health of dentists, dental workers, and patients. Based on the results, the concentration of total fungal and bacterial aerosols increased considerably through dental therapy. Furthermore, the concentrations of TVOCs, CO₂, and PM in the indoor air of the dentistry clinic were risky since particular materials were used for dental procedures, cleaning processes, and also there were a large number of personnel in the room. In this study, the TVOCs levels of the sampling locations exceeded the LEED exposure limit, and the highest TVOCs level was recorded in the PRO (2737 µg/m³). Resins and solvents are the main sources of VOCs in PRO, which are used more than other departments. The volatile compounds such as methyl methacrylate, methanol, and isobutyl-methacrylate are the main ingredients of these materials. Also, relatively high concentrations of TVOCs were recorded in ENDO and PED wards. Endodontic therapy (saving the tooth when the pulp and/or periradicular tissues are damaged) uses endodontic substances. The mentioned materials are commonly applied for disinfecting (irrigants and intracanal medicaments) and filling the pulp in root canal treatment. In PED, pediatric dentists also use volatile composite resin, particularly more highly filled resins and bonding agents for anterior restorative care. Inhalation of low concentrations of this compound for a short period of time may irritate the throat, eyes, and skin. However, chronic exposure may have a negative impact on the skin, liver, and central nervous system [12]. According to the obtained results, even the background concentration of TVOCs in PWA has higher values than the recommended limits. These increases are attributed to the application of detergent

solutions for daily disinfecting and cleaning of work surfaces. In the study of IAQ in the Dentistry Faculty of Athens University, the use of acrylic and Kalocryl® known to source high levels of TVOCs (2000-5500 µg/m³) in the indoor environment of the dental clinic offices. Also, higher background levels than the indoor air limits have been attributed to the use of disinfectants and cleaners at the beginning and the end of the shifts [13]. Similarly in some investigations, increased levels of VOCs concentrations were reported throughout business hours in dental clinics and exceeded occupational standards and guidelines [5, 7, 14]. However, a number of studies reported that VOC compounds in the environment of dentistry were below limits recommended by [15, 16]. The CO₂ levels in the PED ward had greater values in comparison to other dentistry wards owing to the higher quantity of dental staff, active dentists, and patients combined with inadequate ventilation conditions.

The indoor CO₂ level has been proposed as a key factor for the transmission of airborne viruses and a potential proxy for indicating the infection risk of respiratory diseases in the dental clinic [17]. The infection risk of transmission through re-inhaled air can be obtained by comparing the indoor concentration of CO₂ with its background concentration [18]. In agreement with past studies, our data showed that the dental treatment procedure plays a major role in increasing the concentration of aerosols [2, 19, 20]. In periodontics, treatment activities such as scaling and root planning, regenerative procedures (reversing lost tissue and bone), and root surface debridement (removing damaged tissue) may produce high PM concentrations compared to other dentistry wards. However, some factors, such as increasing the number of patients, treatment staff, and students affect the concentration of suspended particles in dental educational clinics. On

the other hand, some past studies reported that although higher concentrations of bio-aerosol were generated through scaling, other aerosol levels reverted to baseline after 10–30 min [20]. Some researchers showed that using an adequate suction system and saliva standard ejectors can significantly reduce PM_{10} . However, lower efficiency was observed in the aspiration of PM_1 particles during dental procedures [20]. Furthermore, $PM_{2.5}$ and PM_1 concentrations are related to bacteria levels. Accordingly, the using standard saliva ejectors with increasing ventilation efficiency can effectively lead to spreading decrease of bioaerosols in the dental environment. In this study, the gram-positive bacteria were dominant and mainly source from human respiratory system, patient mouth, and skin. Several studies have shown that the fungal species of *Cladosporium* and *Penicillium* generally occur in indoor environments and are found to be an important risk for dental staffs [19, 21]. Nevertheless, their presence in the outdoor environment could result in their migration into rooms.

Conclusion

This study provides data concerning the levels of IAQ parameters in an educational dentistry clinic. Based on the findings from this study, dental activities and procedures in the different dental wards may increase TVOCs and PM concentrations. The dental clinic personnel are exposed to elevated levels of TVOCs, airborne bacteria throughout dental cleaning procedures. The results revealed significant correlations between TVOCs with indoor temperature and relative humidity, as well as bacteria concentrations and PM ($PM_{2.5}$ and PM_1). Maximum values of PM concentrations were observed throughout scaling and root planning in periodontics. The quality of indoor air of educational dental clinics

requires special attention and long-term surveillance for the health protection of patients, dental students, and treatment staff. The indoor particles are to be assessed and compared with the standard level by the infection control procedures of dental clinics. The presence of opportunistic microorganisms (*Staphylococcus* spp. and *Streptococcus* spp.) is significant. Also, fungi can be useful indicators of indoor air quality. Furthermore, since *Aspergillus* species may lead to nosocomial infections and allergies, their presence in the indoor environment of dental clinics may be a hazardous. Therefore, controlling airborne particles is to be standardized by infection control actions of dental clinics. Important sources of emissions of indoor air pollutants and the development of appropriate control techniques should be identified.

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Competing interests

The authors declare they have no actual or potential competing interests.

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Ethical considerations

“Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.” This study was approved by the Ethical Committee of Arak University of Medical Sciences with code: IR.ARAKMU.REC.1398.010

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