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Original Article

# Air quality in a hospital dental department

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## KEYWORDS

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**Abstract** *Background/purpose:* Documented studies demonstrated that particulate matter 2.5 (PM<sub>2.5</sub>) are relatively high in dental clinics. However, the PM<sub>2.5</sub> composition is unclear. This study aimed to evaluate the dental department's air quality in a teaching hospital.

*Materials and methods:* The SKC AirChek XR5000 pumps and canister samplers were used to collect PM<sub>2.5</sub> and volatile organic compounds (VOCs). The PM<sub>2.5</sub> composition analysis (polycyclic aromatic hydrocarbons (PAHs) and metals) was conducted, and in the dental clinic and waiting room, the air quality comparison was investigated. Moreover, the dental clinic's air quality was compared before and after air purifier use.

*Results:* In the dental clinic and waiting room, the results revealed high PM<sub>2.5</sub> concentration exceeding the standard of the United States Environmental Protection Agency (USEPA) (35 µg/m<sup>3</sup>); the values were 41.08–108.23 µg/m<sup>3</sup> and 17.89–62.72 µg/m<sup>3</sup>, respectively. In both investigated locations, VOCs had no significant difference. Among 16 priority PAHs, the result indicated high level of benzo(b)fluoranthene (B(b)f), benzo(k)fluoranthene (B(k)f), benzo(a)pyrene (B(a)p), and indenopyrene (IP). B(b)f and B(k)f and lead (Pb) concentrations were detected with a significant difference in the clinic as compared to the waiting room. In addition,

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after air purifier use, the B(b)f concentration in the dental clinic reduced from 0.08 to 0.42  $\mu\text{g}/\text{m}^3$  to 0.06–0.18  $\mu\text{g}/\text{m}^3$  ( $P < 0.05$ ).

**Conclusion:** For dental practitioners, an appropriated air quality regulation needs to be considered, due to high air pollutant concentration. In addition, using air purifier can efficiently reduce air pollutants.

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## Introduction

Among developing countries, air pollution is a serious problem. It has been an issue of public concern and was confirmed to have a huge impact on human health.<sup>1,2</sup> Exposure to fine suspended particles is shown to be associated with worsening asthma, chronic obstructive pulmonary disease, pneumonia, lung cancer, and cardiovascular diseases.<sup>3–6</sup> Fine suspended particles are very tiny particles floating in the air. PM<sub>2.5</sub> have a particle size range of 2.5  $\mu\text{m}$  and are easy to bound with toxic substances such as germs, polycyclic aromatic hydrocarbons (PAHs), and heavy metals. As reported, PAHs bound with PM<sub>2.5</sub> can increase cancer and cardiovascular disease incidence.<sup>7,8</sup> Moreover, volatile organic compounds (VOCs) have been classified as carcinogens by the International Agency for Research on Cancer (IARC), which are thus harmful to the immune system.<sup>9,10</sup> Several metals are neurotoxic and can be toxic even at low levels.<sup>11</sup>

From the chemical point of view, few research focus on air quality status of a dental clinic. Different suspended particle concentrations, physical properties, and composition have different effects on health.<sup>12,13</sup> By chemical composition understanding, the impact of specific components in PM<sub>2.5</sub> can be clarified on the certain environment and human health.

In dental treatment, many factors affect air quality.<sup>14,15</sup> Teeth grinding and drilling and dental material were the principal dental activities to produce particles and aerosol.<sup>16–18</sup> Dental practitioners use a large variety of materials for procedures. Some dental materials have volatile character that might be the main source of VOCs.<sup>19</sup> Documented studies demonstrated that PM<sub>2.5</sub> are relatively high in dental clinics.<sup>14,15,20</sup> However, the PM<sub>2.5</sub> composition is unclear. In this study, PM<sub>2.5</sub> and VOCs were investigated in a dental clinic and waiting room. The PM<sub>2.5</sub> composition (PAHs and metals) was measured and analyzed. A dental clinic's air quality after air purifier use was also evaluated.

## Materials and methods

### Sampling locations

The sampling period is from August 6 to October 31, 2019, each sampling collected during working hour. A dental clinic and waiting room were selected as air sample collection locations. In each selected location, PM<sub>2.5</sub> and VOCs were collected 3 days/week for 8 h. Common environmental pollutants were measured and analyzed.

### Sampling instruments

For air pollutants collecting, two SKC AirChek XR5000 personal air-sampling pumps (SKC Inc, Eighty Four, PA, USA) were concomitantly run with the CS1200E Flow Controller (Entech Instruments, Simi Valley, CA, USA) and evacuated canister sampler (Entech Instruments). PM<sub>2.5</sub> monitoring was conducted using a 37-mm quartz filter paper housed inside a cassette and coupled with SKC AirChek XR5000 personal air-sampling pumps operating at approximately 4.0 L per minute for 24 h.

PM<sub>2.5</sub> concentration was determined by gravimetric analysis in an environmentally controlled room with guidance from the United States Environmental Protection Agency (USEPA) Quality Assurance Guidance Document 2.12 January 2016. PM<sub>2.5</sub> samples were pre- and post-weighed on an electronic micro-balance. The difference between the two weights and the total sample volume determine the PM<sub>2.5</sub> final mass concentration.

For PAHs and metal, PM<sub>2.5</sub> samples were further analyzed. Gas chromatography mass spectrometry (GC–MS) (Agilent, Santa Clara, CA, USA) was used to analyze the 16 PAHs announced by the USEPA, while inductively coupled plasma mass spectrometry (ICP–MS) (Agilent) for metals. Canister samplers were employed for VOCs measurement. VOCs were determined by GC–MS method to identify its emission characteristics.

### Intervention with air purifier

This sampling period is from April 6, 2020, to May 11, 2021, the location is in the dental clinic, and the sequence is to sample with Blueair480i (Blueair, Stockholm, Sweden) and without air purifier. In the first phase, difference in the PM<sub>2.5</sub> concentration and composition between the clinic and waiting room was compared. In the second phase, an air purifier was used to reduce PM<sub>2.5</sub> concentration in the clinic. PM<sub>2.5</sub> samples with air purifier were collected on the first 3 days and then air samples without the purifier for the next sampling time. Air samples were collected for 5 months.

### Statistical analysis

Statistical analysis obtained was made using R 4.1.0 software (R Foundation for Statistical Computing, Vienna, Austria). Since a parametric distribution was not followed, nonparametric statistics were used. Continuous variables were expressed as medians and quartiles. In the groups' comparison, the Mann–Whitney U-test was used. The

statistical tests were two-sided, and *P* values less than 0.05 were considered statistically significant.

## Result

### Concentration of particulate matter 2.5 and polycyclic aromatic hydrocarbons in clinic

The sampling results are shown in Table 1. The maximum sampling concentration of PM<sub>2.5</sub> was 108.231  $\mu\text{g}/\text{m}^3$ , the minimum was 41.078  $\mu\text{g}/\text{m}^3$ , and the median was 79.910  $\mu\text{g}/\text{m}^3$ . The maximum sampling concentration of benzo(b)fluoranthene (B(b)f) was 0.511  $\text{ng}/\text{m}^3$ , the minimum was 0.010  $\text{ng}/\text{m}^3$ , and the median was 0.032  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of benzo(k)fluoranthene (B(k)f) was 0.257  $\text{ng}/\text{m}^3$ , the minimum was 0.005  $\text{ng}/\text{m}^3$ , and the median was 0.016  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of benzo(a)pyrene (B(a)p) was 0.163  $\text{ng}/\text{m}^3$ , and the minimum and median was 0  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of indeno<sup>13</sup>pyrene (IP) was 0.014  $\text{ng}/\text{m}^3$ , and the minimum and median was 0  $\text{ng}/\text{m}^3$ .

### Particulate matter 2.5 and polycyclic aromatic hydrocarbons in waiting room

The maximum sampling concentration of PM<sub>2.5</sub> was 62.731  $\mu\text{g}/\text{m}^3$ , the minimum was 17.888  $\mu\text{g}/\text{m}^3$ , and the median was 46.102  $\mu\text{g}/\text{m}^3$ . The maximum sampling concentration of B(b)f was 0.42  $\text{ng}/\text{m}^3$ , and the minimum and median was 0  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of B(k)f was 0.038  $\text{ng}/\text{m}^3$ , and the minimum sampling concentration and median was 0  $\text{ng}/\text{m}^3$ . B(a)p was undetectable. The maximum sampling concentration of IP was 0.014  $\text{ng}/\text{m}^3$ , and the minimum and median was 0  $\text{ng}/\text{m}^3$ . In this result, PM<sub>2.5</sub>, B(b)f, and B(k)f had higher concentrations in the clinic with significant difference.

### Volatile organic compounds

VOCs concentrations remained lower levels in the clinic lower than the international limits. The analysis results are shown in Table 2. Pentane, Cis-2-butene, Difluorochloromethane,

2-Methylpentane, Isopentane, Toluene, Methyl methacrylate, Acetone, Methanol, and Propane were detected, and there was no significant difference in the concentration between the rooms.

### Metals

The measurements of metal concentration are shown in Table 3. Eleven metals (Iron (Fe), Vanadium (V), Chromium (Cr), Manganese (Mn), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), Lead (Pb)) were identified, of which (Fe), (V), (Cr), (Mn), (Co), (Ni), (Cu), (Zn), (As), and (Cd) had no significant difference between the rooms.

In the clinic, the maximum sampling concentration of Pb in the clinic was 4.829  $\text{ng}/\text{m}^3$ , the minimum was 1.341  $\text{ng}/\text{m}^3$ , and the median was 3.917  $\text{ng}/\text{m}^3$ . In the waiting room, the maximum sampling concentration was 4.621  $\text{ng}/\text{m}^3$ , the minimum was 1.114  $\text{ng}/\text{m}^3$ , and the median was 2.962  $\text{ng}/\text{m}^3$  with significant difference.

### The effect of air purifier

The sampling results are shown in Table 4. Before air purifier use, the maximum sampling concentration of PM<sub>2.5</sub> was 101.8  $\mu\text{g}/\text{m}^3$ , the minimum was 27.6  $\mu\text{g}/\text{m}^3$ , and the median was 31.9  $\mu\text{g}/\text{m}^3$ . The maximum sampling concentration of B(b)f was 0.42  $\text{ng}/\text{m}^3$ , the minimum was 0.08  $\text{ng}/\text{m}^3$ , and the median was 0.19  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of B(k)f was 4.41  $\text{ng}/\text{m}^3$ , the minimum was 0.29  $\text{ng}/\text{m}^3$ , and the median was 0.55  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of Pb was 8.67  $\text{ng}/\text{m}^3$ , the minimum was 5.53  $\text{ng}/\text{m}^3$ , and the median was 6.61  $\text{ng}/\text{m}^3$ .

After air purifier use, the maximum sampling concentration of PM<sub>2.5</sub> was 78.1  $\mu\text{g}/\text{m}^3$ , the minimum was 15.7  $\mu\text{g}/\text{m}^3$ , and the median was 22.3  $\mu\text{g}/\text{m}^3$ . The maximum sampling concentration of B(b)f was 0.18  $\text{ng}/\text{m}^3$ , the minimum was 0.06  $\text{ng}/\text{m}^3$ , and the median was 0.11  $\text{ng}/\text{m}^3$ . The maximum sampling concentration of B(k)f was 4.31  $\text{ng}/\text{m}^3$ , the minimum was 0.18  $\text{ng}/\text{m}^3$ , and the median was 0.23  $\text{ng}/\text{m}^3$ . The highest sampling concentration of Pb was 7.54  $\text{ng}/\text{m}^3$ , the minimum was 4.94  $\text{ng}/\text{m}^3$ , and the median was 5.52  $\text{ng}/\text{m}^3$ .

**Table 1** PM<sub>2.5</sub> and PAHs concentration value in dental clinic and waiting room.

	Clinic					Waiting Room					<i>P</i> -value
	Frequency Distribution			Minimum	Maximum	Frequency Distribution			Minimum	Maximum	
	25th	50th	75th			25th	50th	75th			
<sup>a</sup> PM <sub>2.5</sub> ( $\mu\text{g}/\text{m}^3$ )	61.024	79.910	88.834	41.078	108.231	33.350	46.10 <sup>e</sup>	54.483	17.888	62.731	<0.05
<sup>b</sup> B[b]f ( $\text{ng}/\text{m}^3$ )	0.031	0.032	0.071	0.010	0.511	0.000	0.000	0.000	0.000	0.042	<0.05
<sup>c</sup> B[k]f ( $\text{ng}/\text{m}^3$ )	0.011	0.016	0.035	0.005	0.257	0.000	0.000	0.000	0.000	0.038	<0.05
<sup>d</sup> B[a]p ( $\text{ng}/\text{m}^3$ )	0.000	0.000	0.048	0.000	0.163	0.000	0.000	0.000	0.000	0.000	N.S.
<sup>e</sup> IP ( $\text{ng}/\text{m}^3$ )	0.000	0.000	0.005	0.000	0.014	0.000	0.000	0.000	0.000	0.014	N.S.

<sup>a</sup> PM<sub>2.5</sub>: particulate matter 2.5.

<sup>b</sup> B[b]f: benzo(b)fluoranthene.

<sup>c</sup> B[k]f: benzo(k)fluoranthene.

<sup>d</sup> B[a]p: benzo(a)pyrene.

<sup>e</sup> IP: indeno[1,2,3-cd]pyrene.

**Table 2** VOCs concentration value in dental clinic and waiting room.

	Clinic					Waiting Room					P-value
	Frequency Distribution			Minimum	Maximum	Frequency Distribution			Minimum	Maximum	
	25th	50th	75th			25th	50th	75th			
Pentane	0.630	0.755	1.260	0.410	1.630	0.435	0.780	1.223	0.320	1.300	N.S.
Cis-2-Butene	1.308	1.440	1.545	1.020	1.710	1.208	1.380	1.478	1.070	1.680	N.S.
Difluorochloromethane	0.713	0.770	0.823	0.640	1.090	0.725	0.800	0.860	0.580	1.170	N.S.
2-Methylpentane	0.765	0.825	1.085	0.200	3.210	0.738	0.805	0.880	0.350	3.160	N.S.
Isopentane	2.153	3.045	4.598	1.580	8.720	1.780	3.075	4.365	1.460	4.900	N.S.
Toluene	4.058	4.625	6.543	1.660	12.280	4.020	4.910	7.265	1.710	14.130	N.S.
Methyl methacrylate	6.560	15.245	29.643	3.260	38.780	9.303	14.390	35.940	3.050	40.180	N.S.
Acetone	10.248	12.960	15.865	0.010	21.740	10.805	12.610	13.515	8.960	23.420	N.S.
Methanol	25.948	31.610	34.908	20.780	40.850	24.478	30.710	34.800	20.400	44.840	N.S.
Propane	8.618	14.395	32.133	5.420	39.450	14.025	19.685	36.338	5.250	41.160	N.S.

**Table 3** Metal concentration value in dental clinic and waiting room.

(ng/m <sup>3</sup> )	Clinic				Waiting Room				P-value		
	Frequency Distribution			Minimum	Maximum	Frequency Distribution				Minimum	Maximum
	25th	50th	75th			25th	50th	75th			
<sup>a</sup> Fe	1.375	1.682	1.849	0.934	2.435	1.335	1.696	1.859	0.892	2.321	N.S.
<sup>b</sup> V	43.240	61.579	80.628	36.559	92.897	38.646	43.488	66.686	31.126	100.618	N.S.
<sup>c</sup> Cr	16.056	17.055	20.566	14.783	52.936	15.651	17.071	20.619	14.188	51.144	N.S.
<sup>d</sup> Mn	453.375	486.142	516.323	414.245	728.038	419.712	446.593	472.032	387.175	742.487	N.S.
<sup>e</sup> Co	0.570	0.731	1.031	0.486	1.313	0.458	0.606	0.781	0.390	1.523	N.S.
<sup>f</sup> Ni	37.364	83.615	227.980	20.057	311.720	38.210	82.702	232.354	17.469	322.103	N.S.
<sup>g</sup> Cu	14.877	16.649	19.831	12.439	47.494	14.921	17.483	21.073	14.019	44.780	N.S.
<sup>h</sup> Zn	77.858	110.296	128.379	62.545	199.049	76.289	92.185	124.564	60.342	179.907	N.S.
<sup>i</sup> As	1.293	1.452	1.644	1.005	1.719	1.177	1.208	1.419	1.009	1.818	N.S.
<sup>j</sup> Cd	1.371	1.830	2.102	1.066	2.623	1.218	1.851	2.638	0.964	2.848	N.S.
<sup>k</sup> Pb	2.723	3.917	4.285	1.341	4.829	1.576	2.962	3.833	1.114	4.621	<0.05

<sup>a</sup> Fe: Iron.<sup>b</sup> V: Vanadium.<sup>c</sup> Cr: Chromium.<sup>d</sup> Mn: Manganese.<sup>e</sup> Co: Cobalt.<sup>f</sup> Ni: Nickel.<sup>g</sup> Cu: Copper.<sup>h</sup> Zn: Zinc.<sup>i</sup> As: Arsenic.<sup>j</sup> Cd: Cadmium.<sup>k</sup> Pb: Lead.

## Discussion

PM<sub>2.5</sub>, B(b)f, B(k)f, and Pb values were found to be higher in the dental clinic than in the waiting room, and the VOC concentration has no significant difference in both locations. After air purifier use, the B(b)f concentration in the dental clinic significantly reduced.

In this study, PM<sub>2.5</sub> concentration was higher in the dental clinic than that in the waiting room, in accordance with Helmis et al. and Godwin et al.'s studies,<sup>14,20</sup> and both studies have reduced PM<sub>2.5</sub> concentrations in dental clinics through natural and mechanical ventilation.<sup>14,20</sup> Ventilation may be considered as another option to reduce PM<sub>2.5</sub>

concentrations. As noted in this study, PM<sub>2.5</sub> levels were significantly higher than PM<sub>2.5</sub> standard (35 µg/m<sup>3</sup>) (24-h average) announced by USEPA, and both monitoring sites exhibited relatively high levels exceeding the global air quality guideline limits by WHO. In the dental clinic, PM<sub>2.5</sub> concentrations reach high values. PM<sub>2.5</sub> harm many human body parts, including the nerves, gastrointestinal, heart, lung, liver, kidney, and skin. Long-term exposure may cause allergies, asthma, lung and liver cancer, cardiovascular disease, blood disease, etc.<sup>21</sup>

Various factors influence air quality in hospitals including the use of chemicals, pharmaceutical products, biological contaminants, cleaning compounds, sterilization,

**Table 4** PM2.5, PAHs and Pb concentration value before and after air purifier placement.

	Before Air Purifier					After Air Purifier					P-value
	Frequency Distribution			Minimum	Maximum	Frequency Distribution			Minimum	Maximum	
	25th	50th	75th			25th	50th	75th			
<sup>a</sup> PM2.5 ( $\mu\text{g}/\text{m}^3$ )	30.9	31.9	55.8	27.6	101.8	17.3	22.3	60.4	15.7	78.1	N.S.
<sup>b</sup> B [b]f ( $\text{ng}/\text{m}^3$ )	0.19	0.19	0.29	0.08	0.42	0.10	0.11	0.12	0.06	0.18	<0.05
<sup>c</sup> B [k]f ( $\text{ng}/\text{m}^3$ )	0.38	0.55	2.84	0.29	4.41	0.19	0.23	1.76	0.18	4.31	N.S.
<sup>d</sup> Pb ( $\text{ng}/\text{m}^3$ )	5.66	6.61	8.23	5.53	8.67	5.36	5.52	5.91	4.94	7.54	N.S.

<sup>a</sup> PM2.5: particulate matter 2.5.

<sup>b</sup> B[b]f: benzo(b)fluoranthene.

<sup>c</sup> B[k]f: benzo(k)fluoranthene.

<sup>d</sup> Pb: Lead.

and dust. The places recommended by USEPA are often with a high density of activity people, such as outpatient waiting areas, registration areas, emergency rooms, food courts, and halls, and the air quality standards should be more stringent. Since people who come and go are mostly patients with low resistance, the area needs to be clean for medical procedures, such as the clinic in this study.

It was confirmed that plaster and dental materials' trimming during dental treatment or high-speed hand pieces' cutting causes debris, generating powder layers and fine suspended particles,<sup>22,23</sup> which are possible PM2.5 sources. PAHs usually exist in plastics, rubber, and synthetic resins,<sup>24,25</sup> and in dental practice, there are many materials derived from these, including composite resins for dental caries filling, temporary crown resins, and resin denture base materials with polyethylene terephthalate (PET),<sup>26,27</sup> dental polymer brackets with high-density polyethylene (HDPE),<sup>28</sup> and the impression material made of synthetic rubber.

The average concentration of Pb was measured highly in the clinic. Metal alloys also play important roles in dental practice, including direct and indirect dental restorations and instruments for teeth preparation. Common metals include gold (Au), palladium (Pd), platinum (Pt), silver (Ag), aluminum (Al), Co, and Cr,<sup>29</sup> while Pb is not commonly used. It was found that polysulfide impression materials have Pb components and may be a possible Pb source in the dental clinics.<sup>30,31</sup> In this study, there are significant differences in Pb exposure. Pb is a neurotoxic substance.<sup>32</sup> Lead can exert severe and chronic health effects.<sup>33</sup>

According to the IARC, most of the individual PAHs are classified as either probably carcinogenic to humans (Group 2A) or possibly carcinogenic to humans (Group 2B). There is evidence that B(b)f in PM2.5 increases the risk of individuals to suffer from chronic kidney disease. Various studies have found that there are multiple mechanistic links between B(b)f exposure and kidney damage,<sup>34</sup> and that B(b)f damages DNA and mitochondria, induces early cell apoptosis, and leads to offspring defects. Previous studies not only provided evidence for the toxic effects of B(b)f but also clarified the underlying mechanism of B(b)f inducing oocyte quality reduction.<sup>35</sup> Maternal B(b)f exposure can interfere with the normal sperm function of the offspring, leading to abnormal human male reproductive function.<sup>36</sup> B(k)f has immunotoxicity and induces an

immunosuppressive response.<sup>37</sup> PAHs are famous for their mutagenic and carcinogenic effects. B(a)p and B(k)f, which are environment-related PAHs, can together induce estrogenic effects in the body, which may affect its toxic effects and carcinogenicity.<sup>38–40</sup>

This study demonstrates potential health impact of air quality for dental practitioners. Air purifier use can improve a dental clinic's air quality, and all air pollutants are significantly reduced. In the future, the efficacy of different ways of air quality reduction should be discussed. PM2.5 concentration in the dental clinic is higher than the standards of the Taiwan Environmental Protection Agency and the USEPA. High exposure of B(b)f, B(k)f PAHs, and Pb may cause health hazard to the human body. Air purifier use effectively reduces the air pollutants, and the dental department should establish air quality regulation for dental practitioners, to provide an ideal working environment and occupational safety protection.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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