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Hazard Identification and Physical Parameters Measurement in Dental Laboratories

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Abstract

Substances such as dental materials routinely used in dental procedures such as acrylate compounds, organic solvents, disinfectants can spread into air within the dental working environment and affect the indoor air quality (IAQ). This study aimed to identify the hazards at dental laboratories and measure the physical parameters of IAQ such as particulate matter (PM), temperature and humidity. Hazard identification, risk assessment and risk control (HIRARC) analysis was conducted during walk through survey, then the area monitoring of PM_{10}, $PM_{2.5}$, temperature and humidity was conducted using particle air counter for eight hours at each dental laboratories: Prostethic Lab, Orthodontic Lab, Maxillofacial Lab, Plaster Room, Teaching Lab 1 and Teaching Lab 2. The concentration of PM_{10} and $PM_{2.5}$ were below the acceptable level at each laboratory except for PM_{10} at the Prostethic Lab (205.8 µg/m^3 in 2018 and 163.0 µg/m^3 in 2020) which were above 150 µg/m^3 as referred to the Industry Code of Practice on Indoor Air Quality 2010 by the Department of Occupational Health and Safety, Malaysia. It is important to assess the HIRARC and determine the physical parameters in dental laboratories to ensure the safety and health of the workers are guaranteed. Hence continuous monitoring and training should be conducted to ensure the prevention and control measures are efficient.

Keywords: Dental laboratories; HIRARC; Particulate matter; PM_{10}; $PM_{2.5}$.

1.0 INTRODUCTION

The presence of air contaminants in enclosed environment has become an issue of concern as an individual spends most of their time indoors. Public concern about the adverse effects of indoor air has increased in recent decades. Beginning in the 1970's, occupants of commercial and institutional buildings began to report health problems related to the buildings they inhabited. Amongst the common complaints reported in such cases are upper respiratory tract and eye irritation, headache, fatigue, lethargy, breathing difficulty and asthma. Cases reported are on the rise particularly in schools and commercial buildings [1]. Wider observation on this matter has also raised concerns over health problems caused by indoor air quality. This is because, it reduces the productivity of the occupants in the building indirectly. Low indoor air quality (IAQ) can affect employee productivity due to high absenteeism and sick leave records [2].

IAQ is influenced by thermal comfort and air pollutants. Thermal comfort is influenced by temperature, humidity and air movement, while air pollutants can come from airborne particles, volatile organic compounds, tobacco smoke, asbestos, formaldehyde, radon, gas combustion and ozone. Air pollutants also include various biological materials and organisms produced by building materials, human activities, office equipment and even outdoor activities [3]. Suspended particles or particulate matters are mixture of solid particles and liquid droplets found in the air whether composed of organic or inorganic matter. The types of particulate matter include coarse and fine particles. PM_{10} is a course particle

which also known as inhalable particles that has the size less than 10 µm in diameter. It is a mixture of materials that include smoke, soot, dust, salts, acids and metals. While fine particles or $PM_{2.5}$ which is also known as respirable particles that has the size less than 2.5 µm in diameter [4].

Temperature has a strong correlation with employee performance in a building. Mendell and Heath [5] found that the occupants reported a decrease of self-performance and an increase of difficulty in concentrating and thinking when the temperature increase from 22ºC to 26ºC and 30ºC. Thermal comfort is achieved when at least 80% of the occupants in a room or building feel comfortable. Relative humidity below 25% will increase discomfort and drying of the mucous membrane and skin which cause irritation. Whereas high humidity will cause condensation inside building structures and indoor or outdoor surfaces resulting in fungal growth. Comfort with thermal environment is also influenced by factors such as radiant heat, air velocity, level of occupant activity and type of clothing. Air movement in a building is an easily identifiable comfort parameter representing air displacement by ventilation. If the movement of air in the occupied space is insufficient, it can lead to a feeling of congestion. But excessive air movement can cause unwanted draught or local cooling of the human body [6]. The problem of IAQ arises when the quality of air supplied from the ventilation system is insufficient for the amount of pollutants present in the space or room. Hence, IAQ and mechanical ventilation and air conditioning system have a close relationship. Ventilation means the process of supplying or removing air from a space for the purpose of controlling the level of air pollutants, humidity or temperature. The main purpose of ventilation is to provide acceptable IAQ by diluting and removing pollutants in the indoor air [7]. Building ventilation can occurs naturally, mechanically or a combination of both.

Normally, a workplace inspection, incident injury or illness report and employee complaint and observation will be done before the IAQ monitoring and measurements are conducted. These steps are part of the hazard identification, risk assessment and risk control (HIRARC) process, which is necessary to understand the nature of the hazards involved that are commonly found in the workplace, as to determine the exposure level of the person to the identified hazard through calculation of risk level, likelihood and severity. Finally to determine and apply the appropriate control measures with respect to the source and type of the hazard including substitution, isolation, engineering and administrative controls, and personal protective equipment [8].

As reported by the United States (US) Department of Labour, poor air quality is the number one health concern among dental laboratories because they are usually located in commercial or residential building enclosures and the capture and evacuation of airborne dust from normal operations can be difficult. Dental technicians was also ranked as the fourth unhealthiest job in the US in 2017 [9]. Occupational Safety and Health Administration (OSHA) estimated that low air quality can cause an organisation to lose 14 to 15 minutes of working time per employee for each day [5]. In 2008, the Ministry of Health, Malaysia has spent RM1.8 million on cleaning work when Ayer Keroh Community Polyclinic building in Melaka was full of fungus due to high humidity. A fungal contamination like this also happened at Sultan Ismail Hospital, Johor Bahru in 2004 where its construction which cost RM557.8 million had to be temporarily closed. A similar case occurred in 2011 at Public Service Department in Cyberjaya [10, 11]. A previous study in Kelantan state of Malaysia involving reported a significantly higher personal monitoring exposure of PM_{10} among dental laboratory technicians compared to administrative staff ($p<0.05$) [12]. Therefore, this study aimed to identify the main hazards at dental laboratories based on HIRARC analysis and investigate the IAQ levels in particular the physical parameters of particulate matter, temperature and humidity.

2.0 METHODOLOGY

2.1 Walk-through survey and HIRARC

Walk-through survey was conducted to identify the dental laboratory plan layout in determining the suitable sampling site for measurement of particulate matters and to gather information on work task description based on the checklist following Industry Code of Practice on Indoor Air Quality 2010 [7]. The walk-through survey involved six dental laboratories namely Prostethic Lab, Orthodontic Lab, Maxillofacial Lab, Plaster Room, Teaching Lab 1 and Teaching Lab 2. The building inspection was also conducted to gather information such as human exposure and potential source of contaminant at the sampling point. Based on the walk-through survey and work task information provided by the person in charge at the respective workstation, the safety and health risks can be determined hence the HIRARC was performed accordingly. The basic information on the factors which affect indoor air quality were also obtained through this survey.

2.2 Measurement of physical parameter (particulate matter, temperature and humidity)

Measurement of physical parameter such as particulate matter ($PM_{2.5}$ and PM_{10}), humidity and temperature were conducted in the year 2018 and 2020 using Handheld 3016 IAQ Airborne Particle Counter (Lighthouse, USA). There were six sampling sites selected at each dental laboratory for the area monitoring which was decided based on the significant sources of particulate matters exposure from the work operations (based on the walk-through survey). The placement of Handheld 3016 IAQ Airborne Particle Counter (Lighthouse, USA) at the chosen site of sampling followed the standard procedure as stated in the Industry Code of Practice on Indoor Air Quality 2010 [7]; such as minimal

disturbance of work activities in the study area, at least 0.5 metre from corners or windows, partition, and other vertical surfaces, not directly in front of air supply diffusers, induction units, floor fans, or heaters, or the exhaled breath of the operator, not under direct sunlight and etc. All the sampling session were started from 9:00 a.m. to 5:00 pm, an average of 7 hours per sampling site. The particle counter was set to collect measurements of the physical parameters at 15-minute intervals, up for 28 cycles. After that, the room volume were measured in cubic feet by using measuring tape.

3.0 RESULTS AND DISCUSSION

3.1 Walk through survey and hazard identification

There were six dental laboratories that had been monitored: Prostethic Lab, Orthodontic Lab, Teaching Lab 1, Teaching Lab 2, Plaster Room and Maxillofacial Lab. Majority of the dental technologists work in normal shift from 8 am to 5 pm. General observation made found that several ceilling were spotted with stains and moulds, no window built and the mechanical ventilation were not adopted except for plaster room having four (4) airducts, hence the rest of the laboratories have no fresh outdoor air intake.

Prosthetic lab was occupied by eight (8) dental laboratories who worked on retainer, dentures, repair or restore missing teeth and mostly focused on intraoral defects, mainly they work on making artificial teeth for implant treatment. The work task and procedure in prosthodonthic laboratory consists of polishing and grinding, sandblasting and mixing and investing. The number of technologists located in this laboratory is overcrowded as based on the volume of the room, only three workers should be occupied in this laboratory instead of eight, making the technologists feel uncomfortable performing their work.

The orthodontic lab involves five work tasks which are soldering, wire bending, trimming and polishing, drying and making orthodontic appliances and were conducted by two dental technologies. Soldering is a process of combining metals by the fusion of filler metal at high temperature, exposing workers to physical and chemical hazards. Wire bending is a process of bending the arch wires in order to ensure teeth move in the angle that the orthodontist favours. Normally, the arch wires used are made of Nickel and Titanium. The sharp ends of the wire can cause physical hazard such as risk of getting punctured and bleed. Trimming and polishing orthodontic plates task is to remove excess resin by using modern micromotors. The hazards involve in this task include biological and ergonomic hazards. The dust may cause respiratory and inhalation problem like asthma to the workers besides irritation to the skin and eyes. In addition, trimming and polishing require the technicians to be in sitting position and focus on the small piece of dental plate for a long time. This condition gives ergonomic hazards to them as they may developed low back pain and eyestrains. Drying task involves drying the orthodontic plates inside the oven. The hazard that the workers may face during handling the oven is physical hazards. The other task is vacuum forming process to make orthodontic appliances like retainers or mouth guard using a vacuum suction. This work task is done by heating a piece of thermoplastic sheet which then will be pressed against the mould by a vacuum. Similar to the usage of oven, usage of vacuum suction also produces a physical hazard which is heat.

Maxillofacial prosthetics in maxillofacial lab is the work process that involves rehabilitation of patients that have disabilities or defect that were present when born or develop due to disease or trauma. Prostheses are often needed to replace missing area of bones or tissues and restore oral function such as swallowing, speech and chewing. On the other hand, a prothesis for a face or body may be indicated for cosmetic and psychosocial reasons. Hence, the work description of the maxillofacial prosthetic is only involving making prosthetics teeth, eye and nose. There were two workers in this lab who do their job while sitting on the chair, leading to ergonomic risk. The first step in work process of maxillofacial prosthetics is studying the model like teeth or eye of the patients and do the impression to imprint the missing part of teeth or face to make the model. Before that, technologist will take the measurement of the missing part like teeth, eye or nose. After that, they will do impression tray or special tray. This process involves in using chemicals materials, such as vinyl polysiloxane impression material that is used in the ocular prosthetics. Before final impression, a special tray is evaluated for any overextension in ocular effect. Besides, they will create a hole inside the special tray and coat it with adhesive and vinyl polysiloxane light body administered using a syringe. For a teeth prosthetics, the special tray process is made up of light cure resin materials, auto polymerizing acrylic resin, vacuum-form poly vinyl, thermoplastic materials and using cold cure acrylic. After they finish with the special tray, they will do a wax-up. The part like teeth or eye will be completely waxed, such as for a tooth, they will do diagnostic wax-up to establish the correct positioning of teeth to ensure proper outcome and proper function. Lastly, the prosthetics teeth are ready to be in positioning and replacement.

The plaster room was occupied not only by workers but also dental students. Usually, about 10 to 15 people occupied the room per session and each session took two to five hours depending on the work process conducted. Activities that being carried out is making a denture. Denture is a removable replacement for missing teeth and surrounding tissues. Two types of dentures were available which are complete and partial dentures. Some of visible contaminants can be seen from the use of certain detergents and plaster of Paris that can produce fine dust circulating air in this room.

Teaching Lab 1 and 2 have been used for teaching purposes, with a lot of workstations provided for both technologists and students to perform their work task. Some of the technologists prefer to use this area instead of the actual workplace that has been assigned for them because of this area is more spacious and comfortable. Based on the

walkthrough survey, their work may be exposed to many hazards, for example, physical hazards, chemical hazards and the ergonomic hazards. Table 1 summarises the hazard identification and risk rating at the dental laboratories.

Table 1. Hazard identification and risk rating at dental laboratories

Hazard Identification		Work activity	Location	Risk Rating
Physical	Heat and flame (e.g from Bunsen burner, dental lamp)	Soldering, Drying, Vacuum forming process	Orthodontic	2
		Constructing the denture mould process, tooth arrangement process	Teaching Lab 1	3
	Sharp (Nickel-Titanium) arch wires	Wire bending	Orthodontic	1
	Noise from dental equipment	Maxillofacial prosthetist	Maxillofacial	6
		Silicone polisher drilling	Teaching Lab 1	8
		Trimmer and low speed handpiece	Orthodontic	9
Chemical	Exposure to butane gas	Soldering	Orthodontic	2
	Strong odour	Work process handling acrylic resin	Maxillofacial	6
	Volatile organic compound	Maxillofacial prosthetist	Maxillofacial	3
	Use of methyl methacrylate	Constructing the denture mould process	Teaching Lab 1	8
	Respirable dust	Trimming and polishing	Orthodontic	2
		Finishing and polishing process of denture mould	Teaching Lab 1	8
		Dental casting and plaster sanding	Plaster room	9
	Exposure to trayplast	Prostheses work	Prosthetic	8
Ergonomic	Long and bad sitting posture that may cause back pain, prolonged visual effects as well as repetitive motion.	Trimming and polishing	Orthodontic	6
		Maxillofacial work	Maxillofacial	6
		Tooth arrangement process	Teaching Lab 1	4
		Prostheses work	Prosthetic	12
		Dental casting and plaster sanding	Plaster room	4

3.2 Measurement of particulate matter (PM), temperature and humidity

Dental laboratory technicians have multiple occupational exposures, which may have adverse effects on their health. The potential occupational risk factors include chemical, physical, biological and other job-related factors as described previously. Exposure to physical risk factors include nuisance dust, noise, vibration, machinery and working space. Chemical risk factors consist of gases, fumes, vapours and liquid. While biological risk factors include infection, bacteria and viruses.

Dental materials comprise of a widely different composition, such as metals, resin-based synthetic polymers, cements and impression materials that could lead to the significant exposure of dust among dental technicians. Dust is generally understood to be an aerosol of solid particles, mechanically produced, with individual particle diameters of 0.1 µm upwards. There are three dental procedures that promotes dust formation which are polishing and grinding, sandblasting and mixing and investing.

Table 2. Average concentration of particulate matters ($PM_{2.5}$ and PM_{10}) and readings of physical parameters (temperature and humidity) at each dental laboratory between the year 2018 and 2020

No	Dental Laboratory	Particulate Matters				Physical Parameters			
		$PM_{2.5}$ (ug/m^3)		PM_{10} (ug/m^3)		Temperature (°C)		Humidity (%)	
		2018	2020	2018	2020	2018	2020	2018	2020
1.	Prostethic Lab	20.6	41.0	205.8	163.0	23.2	27.7	67.6	41.0
2.	Orthodontic Lab	3.3	8.5	19.9	89.3	22.3	25.6	26.2	53.4
3.	Maxillofacial Lab	6.7	14.0	25.5	44.0	23.2	27.7	67.6	41.0
4.	Plaster Room	7.5	8.2	69.7	100.2	23.2	27.1	67.6	36.0
5.	Teaching Lab 1	8.1	12.4	42.6	42.2	22.4	26.9	65.4	34.0
6.	Teaching Lab 2	12.3	10.8	60.3	41.4	22.6	22.2	26.2	34.7

Table 2 shows the average concentration of particulate matter ($PM_{2.5}$ and PM_{10}) as well as temperature and humidity at each dental laboratory, for monitoring conducted in the year 2018 and 2020. The highest readings for both $PM_{2.5}$ and PM_{10} were recorded at prosthetic lab, compared to other locations which might be contributed by overcrowding and work task. The PM_{10} concentration at prosthetic lab had exceed the permissible level for both years, 205.8 µg/m^3 and 163.0 µg/m^3 respectively. According to the Department of Occupational Health and Safety, Malaysia, the maximum size of particle for PM_{10} must not exceed 150 µg/m^3. This is in accordance with the reported significant higher personal monitoring exposure of PM_{10} among dental laboratories compared to administrative staff ($p<0.05$) [12]. Although we are not comparing such measurement with the outdoor air level, however in broader view, National Ambient Air Quality Standards (NAAQS) is another set of criteria for assessing ambient air quality and monitoring of fresh air introduced by

heating, ventilation and air conditioning (HVAC) systems established by US EPA [13]. Whereas, based on the New Malaysia Ambient Air Quality Standard implemented in 2020 replacing the older guideline that has been used since 1989, the level of outdoor PM_{10} should not exceed 100 μg/m^3 and $PM_{2.5}$ must not exceed of 35 μg/m^3 in a 24-hour average [14]. It is something worth to look at as the ambient exposure has been recently revised (2020) yet the indoor air quality permissible level was still following ICOP-IAQ 2010. However, the temperature and humidity are within acceptable limit for majority of the dental laboratories as according to the Department in Occupational Safety and Health [7], the standard air temperature should be between 23-26 ^{0}C and humidity within 40-70%. Relative humidity below 25% can lead to discomfort and drying of the mucous membrane and skin [5]. Temperature control and humidity indoors are essential to maintain thermal comfort in buildings. This thermal comfort will affect productivity, quality of work and human health. The thermal comfort of the building can be influenced by the interior of the building, the openings of the building, the landscape environment, the temperature of the building whether hot or cold. Thermal comfort is achieved when at least 80% of the occupants feel comfortable [5].

3.3 Limitation of Study

A few limitations were encountered in conducting the hygiene monitoring such as measurements of room volume were performed to relate with the occupancy however only analysed data of whether overcrowded or not were recorded, not the measured room volume hence it was decided to omit such information. The HIRARC were conducted thoroughly and risk rating was analysed by taking into consideration existing control but the findings were summarised and simplified (Table 1) to suit with the scope of this article. The presented results also only covered the year 2018 and 2020 although the hygiene monitoring were conducted annually. The reason being, in the year 2019, there were missing data from some of the dental laboratories hence the exclusion. As the scope of the article focused on the hygiene monitoring part only although health effects such as the symptoms should also be asked according to ICOP-IAQ 2010 [7], however no ethical approval were sought hence such data was not included. It is suggested that for future study, such information is to be considered.

4.0 CONCLUSION

The dental laboratory workers were potentially exposed to the hazards due to their work tasks, such as the physical hazards, chemical hazards, biological hazards and ergonomic such as heat and flame, chemical substances, respirable dust and bad sitting posture respectively. The particulate matter concentration (except for PM_{10} at prosthetic lab) were within the standard level. However, all these hazards need to be properly handled and prevented following the hierarchy of control measures such as engineering control to provide exhaust ventilation at all rooms (not only the plaster room). Administrative controls such as housekeeping and schedule rotation to minimise overcrowding at one time are also recommended.

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