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Dental Ventilation Theory and Applications

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Dental facilities need special ventilation considerations because of the work typically performed at such facilities. Bioaerosols and particulates are routinely generated by most dental procedures, e.g., teeth cleaning, scaling, drilling, etc., and are (potentially) at concentrations of concern. Analgesia with nitrous oxide is another concern.

Unfortunately, guidance on ventilation design for dental offices is limited. ASHRAE does not offer guidance on ventilation for dental spaces. Neither *ANSI/ASHRAE Standard 62-1989: Ventilation for Acceptable Indoor Air Quality*[1] nor the *ASHRAE Handbook—HVAC Applications*[2] address this space utilization. The lack of a national design standard leads to the presumption that many dental offices have ventilation designs suited for nominal office usage. This may contribute to marginal indoor air quality (IAQ) in the dental setting.

The published literature[6,7,8,9,10,11,12] documents the potential exposure to airborne contaminants at levels of concern. A well-engineered ventilation design should provide acceptable indoor air quality for the dental professionals in the office, as well as the patients.

Indian Health Service

Dental Space	Total[1] (ACH)	OSA[2] (ACH)	Pressure[4]	Filtration[3]
Dental Operatory	10	2	–or N	90%
Clean Up Alcove	10	2	N	90%
Laboratory Room	6	2	N	90%
Darkroom	10	2	N	90%
Orthodontic X-Ray	2	2	V	90%
Reception	2	2	V	90%
Department of Defense				
General/Prophylaxis	6	2	–	25%
Laboratory	12	3	N	25%
Oral Surgery	12	3	P	90%
Periodontic	12	3	P	90%
X-Ray Film Proc	10	2.5	N	25%
Dental X-Ray	6	2	P	25%

Notes
1. Minimum total air changes per hour.
2. Minimum air changes of outdoor air per hour.
3. ASHRAE dust-spot efficiency.
4. Relative (room) pressurization
N = negative
P = positive
– = neutral
V = variable

Table 1: Ventilation requirements for dental areas.

Background

This article deals with areas typically associated with dental units within institutional facilities, e.g., medical centers, health clinics. These dental units typically consist of areas as listed below:

- Dental operatories (individual and multiple chair areas).
- Reception/waiting area/office administration.
- Clean-up alcove.
- Laboratory/dental technician area.
- Darkroom.
- Restrooms and janitor's closets.

Nationally, the ventilation criteria appear to be limited to criteria of two federal agencies, i.e., Public Health Service (PHS)/Indian Health Service (IHS)[3] and Department of Defense (DoD).[4,5] *Table 1* shows the ventilation criteria for both agencies. (The DoD documents lists criteria for many more dental space categories than are listed in *Table 1*.) There is only limited corroboration between the IHS and DoD ventilation requirements. For example, the Indian Health Service (IHS) recommends 10 ach for a dental operatory. This is 67% more than the DoD standards (depending on the DoD room type). Another significant difference is the less stringent filtration requirements of DoD for the "general/prophylaxis" and laboratory areas.

The IHS criteria indicate both neutral and negative pressurization for the dental operatory. The dental operatories are usually designed to be of neutral pressure. However, enclosed operatories are usually designed to be of negative pressure to afford containment of nitrous oxide,

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infectious airborne contaminants, etc.

Most local jurisdictions do not address dental spaces. Consequently, the *de facto* design for dental spaces is commonly the same as ventilation considered satisfactory for office environments.

Dental Operatories

Several studies have shown the nature and magnitude of bioaerosal contamination in dental operatories. *Table 2* indicates the characteristics of bacterial aerosols generated from the oral cavities of patients by selected dental procedures as reported by Miller and Micik.[6] Dental aerosols and "splatter" are of considerable concern.[6,7,8,9,10,11] Fine aerosols generated by high-speed dental equipment consist of moisture droplets and debris usually five microns in size.[9] "Splatter" consists of particles, usually of a visible size, e.g., 50 microns or larger. The particles are generated during dental procedures and remain airborne only for seconds.[6]

A recent study conducted at a University of Michigan dental clinic concluded that aerosols produced during caries excavation contain high proportions of *Streptococci mutans* and *S. sanguis*. This study revealed peak measured bacteria levels of 200 colony forming units (CFU), per 10 seconds of drilling, at the breathing zone of the operator.[10] (This was in comparison to measured bacteria levels of 4 cfu, per 10 second period, in the ambient air prior to the dental drilling.)

Dusts generated during "restorative dentistry" have also been studied.[20] Research[12] indicates that "15% of the dust mass generated during high-speed finishing of composites is respirable, which is sufficient to warrant concern for the health of dental personnel. . ."

It is important to be aware of some special devices/equipment used in dental operatories such as:

1. High volume evacuators (HVE): These devices are characterized by a volumetric flow of approximately 6-15 cfm (3-7 L/s). The proper/judicious utilization of the HVE provides a highly efficient method for capturing the contaminants generated during dental procedures.[6] Source control is an efficient process to manage IAQ.

2. Air drills: These drills operate at 400,000 rpm and are known to be a dominant source for aerosol generation. Air drills, which do not exhaust spent air, have been advocated for some time.[6] Nonetheless, air drills, which exhaust spent air (at 24 L/min), are still common.

3. Saliva ejectors: These are not considered to have any appreciable effect on the containment of aerosols.

Mickelsen, et.al., report that "waste anesthetic" scavenging systems, by themselves, have not proven to be effective in controlling nitrous oxide (N_2O) in the operatory.[13] They suggest that auxiliary ventilation systems can provide effective control. (Their research indicated that a 3-in. (76 mm) diameter duct with a 3-in. (76 mm) diameter "non-flanged hood opening" and 250 cfm (118 L/s) was one effective arrangement.)

Current filtration technology can not provide effective control of nitrous oxide at the concentrations encountered in dental operatories.

A consideration for air distribution/general ventilation includes placing return (exhaust) grilles low. Generally, it is good practice to design the ventilation in dental operatories to incorporate exhaust grilles located low in adjoining walls. The basis for this design revolves around the higher density of nitrous oxide and is an effort to remove that nitrous oxide leaking past the scavenging system. (At least one study indicates that the leaking of nitrous oxide from the delivery system does not appear to be a significant issue.[13]) The specific gravity of nitrous oxide at 24°C (75°F) is 1.53 (whereas air = 1). Additional benefits include: 1) the avoidance of short circuiting the supply air to the return grille[14] (which is exacerbated by small room sizes) and 2) the provision of a pseudo-displacement ventilation effect.

In the late 1960s, (HEPA-filtered) laminar airflow systems were studied and their performance was affirmed to be effective in this application.[15] Their benefit-to-cost ratio, however, has not enticed many dentists to adopt these systems.

Procedure	Rate of Production* (cfu per min)	Percent ≤5 microns
Examination	3	-
Scaling	1	-
Wash teeth (water stream)	10	-
Prophylaxis (pumice)	42	43
Cavity preparation (air turbine hand piece, air coolant)	58	80
Dry Teeth (air spray)	72	65
Cavity preparation (air turbine hand piece, water coolant)	1,000	95
Polish restoration (bristle brush)	2,300	55
	*median value	

Table 2: Characteristics of bacterial aerosols generated during dental procedures.[6]

Clean-Up Alcove/Area

These areas serve a similar function as a hospital central sterile supply suite. However, in the case of dental clinics, the cleanup/sterilization area is often located in an alcove in close proximity to the patient care area. The cleaning and sterilizing of dental instruments may result in exposure to glutaraldehyde or other toxic chemicals.

The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for glutaraldehdyde is at a ceiling level of 0.2 ppm, which is the concentration that should not be exceeded during any part of the working day. Reports of adverse health effects to employees at levels below 0.2 ppm convinced the ACGIH to publish a new ceiling level of 0.05 ppm in the 1995-1996 Notice of Intended Changes.

Glutaraldehyde has the following physical characteristics:

2% Glutaraldehyde solution:

Specific Gravity: 1.06

vapor pressure: 0.0012 torr at 20°C

vapor density (with reference to air at 1) = 0.64

Glutaraldehyde is a high level disinfecting solution utilized especially for instruments which are intolerant of steam sterilization temperatures. Glutaraldehyde is a known respiratory

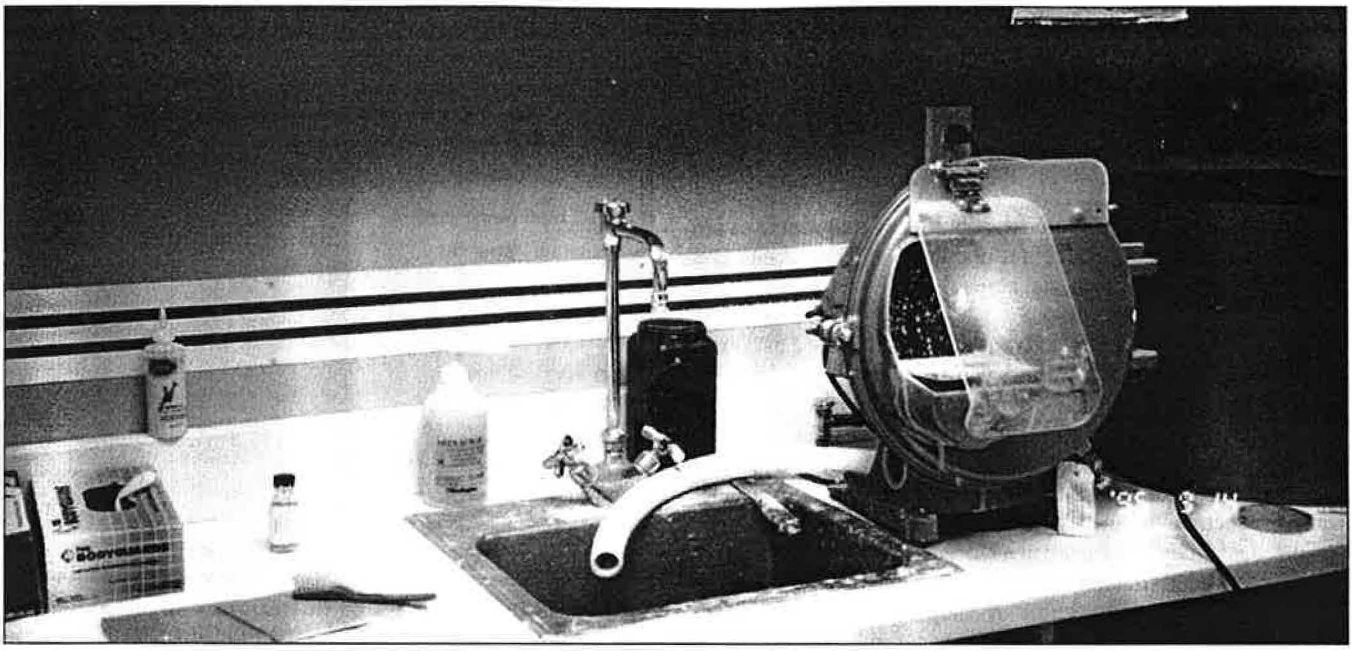

Fig. 1: Dental lab exhaust reduces exposures and captures contaminants.

sensitizer and the ACGIH has established a TLV as indicated above. Source control is a good approach to addressing this chemical. One effective measure is to store the solution in containers with tight fitting lids. However, additional (ventilation) controls are necessary to reduce employee exposure. A design with a slot exhaust located behind the sink (similar to the ACGIH design for welding hoods[16]) is more effective than an overhead exhaust unit. This design pulls the vapor away from the dental staff.

The most important factor for an efficient exhaust system is securing sufficient capture velocity, e.g., 150 fpm (.76 m/s). The exhaust must be discharged directly outside. Qualitative assessments indicate that performance has been satisfactory on a number of designs based on an exhaust of approximately 600 cfm (283 L/s).

Glutaraldehyde usage is declining in the dental setting, due to development of instruments that can be sterilized by heat. As a matter of policy, some institutions do not use glutaraldehyde to avoid the potential toxicologic concerns.

In lieu of glutaraldehyde, some clinics use "gas-claves" to sterilize instruments. These units use a heated mixture of formalin and methanol or isopropanol. Because of the rising effect of the warm vapors, a canopy design is effective in capturing fugitive emissions from the units.

Dental Laboratory

Dental laboratories can be freestanding separate facilities, separate spaces from the dental office, or integral with the dental space. The IAQ in dental lab areas is problematic and suspected to be a source of occupational airway disease, e.g., pneumoconiosis.[17,18,19]

Dental lab technicians are potentially exposed to various dusts such as silica, silicon carbide, ceramics (such as porcelain), and metallic alloys, e.g., beryllium. Dust arises from cutting, grinding, polishing, centrifuge casting (gold), soldering and gypsum and investment works.[18] (Dental casting investments are often made from silicate or phosphate bonded materials.) Over the past 30 years, numerous scientific papers have associated respiratory disease with the dental lab environment.[17,18,19] Brune,et.al.[19] characterize the particle size distribution and report that the predominance of dust particles generated are of a respirable size, i.e., less than 5µm. To reduce exposures and capture the contaminants, increasing numbers of facilities are being constructed with slot-type exhausts installed on the wall, above the countertops, approximately at bench level (see *Figure 1*).

X-Ray Development/Darkroom

The major chemical hazards in x-ray film development processing chemistry are acetic acid (a respiratory irritant), glutaraldehyde (used because of its propensity to harden the emulsion), hydroquinone (a suspected carcinogen and dermal sensitizer), as well as approximately eight other chemicals. Traditionally, dedicated exhaust systems have been provided. The exhaust should always be ducted directly outside.

Ventilation System Overall

Dental spaces need a separate system from adjacent spaces. Central systems with constant volume are the simplest solution to maintain the desired pressure relationships. Even then, most dental plans provide considerable openness between spaces. Even when doors are provided, such as for individual operatories the doors are often kept open. Consequently, space pressurization may not be feasible, which may necessitate a ventilation design with increased ventilation rates.

Segregation of discrete areas, including construction of sealed slab-to-slab walls, is necessary to prevent undesired cross contamination. The types of dental procedures determine the viability of re-circulating the air, as well as the amount of air re-circulation that may be allowed. The location for the direct exhaust must be carefully considered. Lab spaces

See Ninomura, Page 52

Ninomura, From Page 50

should have a negative pressure with respect to other spaces.

Eighty to ninety percent filters are recommended for this application, based on their reported high efficiencies for particulate removal in the range of 1µm to 5µm.[21] The minimum should be filters rated at 60-80%. The higher total ventilation rates indicated in *Table 1* are beneficial only when filtered to the level appropriate for the particulate sizes.

ACGIH recommends a TLV for N_2O exposure of 50 ppm at an 8 hour TWA. A recent report from NIOSH proposed a recommended exposure level (REL) of 25 ppm during the administration of the analgesic.[14] However, they concluded that scavenging systems need to be augmented by auxiliary exhaust systems that keep the exposure below the REL.

Summary/Recommendations

Use of ventilation criteria recommended by the previously referenced federal agencies has provided generally satisfactory results. But, considering the particulates/contaminants that are present, it seems prudent to equip the ventilation system with filters rated at ASHRAE dust spot 60% or higher. (Note: The ventilation design, for a closed operatory where nitrous oxide is to be used, should be capable of providing outside air ventilation of at least 50 cfm/person [25 L/s]—equivalent to 10 ach.)

The use of N_2O, the selection of sterilization methods, and dental procedures such as the use of HVEs can significantly impact the IAQ in dental spaces. These issues have been largely beyond the ken of (HVAC) designers. Yet, acknowledging these factors is critical to designing an effective HVAC system for a dental facility.

A national standard for ventilation requirements for dental areas would be a valuable reference for designing such spaces. Research needs to be conducted to provide data to support the development of such a standard. ASHRAE should consider inclusion of dental areas within their Handbook chapter for healthcare facilities.

Disclaimer

This paper reflects the views of the authors and does not necessarily reflect those of the Indian Health Service.

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