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REDUCTION OF MICROBIAL CONCENTRATION IN AIR OF DENTAL OPERATING ROOMS BY HEPA FILTRATION

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ABSTRACT

Microbial aerosols are known to be created and disseminated in dental operating rooms (DOR's) in quantities sufficient to raise the possibility of cross infection. The purpose of this study was to evaluate the effectiveness of high efficiency particulate air (HEPA) filters in reducing the concentration of airborne microorganisms. Tests were made in DOR's of 1600-, 1800-, and 3240-ft^3 capacity with an 800-cfm HEPA filter unit. Concentrations of microorganisms were measured 4 times daily at approximately 2- to 3-hour intervals. Samples were taken in each DOR with 1-hour Reyniers air samplers drawing 1 cfm for 2 weeks without air filtration and then for 2 weeks with air filtration. In a DOR used for routine scaling with an ultrasonic instrument, the mean microbial air count of 21 viable particles (VP)/ft^3 without air filtration was reduced 90 percent when the air was filtered. In this DOR, peak recoveries of 185 VP/ft^3 without air filtration were reduced 84 percent when the air was filtered. Bacteria recovered during peak periods were predominantly alpha-hemolytic streptococci of the viridans group. In two DOR's used only for routine operative dentistry, microbial air counts were lower, with mean values of 3-8 VP/ft^3 and peak values of 8-26 VP/ft^3 without air filtration. These concentrations were reduced 65 percent when the air was filtered. It was concluded that under normal working conditions an 800-cfm HEPA filter unit is effective in reducing the concentration of airborne microorganisms in a DOR by about 70 percent.

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13. ABSTRACT Microbial aerosols are known to be created and disseminated in dental operating rooms (DOR's) in quantities sufficient to raise the possibility of cross infection. The purpose of this study was to evaluate the effectiveness of high efficiency particulate air (HEPA) filters in reducing the concentration of air-borne microorganisms. Tests were made in DOR's of 1600-, 1800-, and 3240-ft^3 capacity with an 800-cfm HEPA filter unit. Concentrations of microorganisms were measured 4 times daily at approximately 2- to 3-hour intervals. Samples were taken in each DOR with 1-hour Reyniers air samplers drawing 1 cfm for 2 weeks without air filtration and then for 2 weeks with air filtration. In a DOR used for routine scaling with an ultrasonic instrument, the mean microbial air count of 21 viable particles (VP)/ft^3 without air filtration was reduced 90 percent when the air was filtered. In this DOR, peak recoveries of 185 VP/ft^3 without air filtration were reduced 84 percent when the air was filtered. Bacteria recovered during peak periods were predominantly alpha-hemolytic streptococci of the viridans group. In two DOR's used only for routine operative dentistry, microbial air counts were lower, with mean values of 3-8 VP/ft^3 and peak values of 8-26 VP/ft^3 without air filtration. These concentrations were reduced 65 percent when the air was filtered. It was concluded that under normal working conditions an 800-cfm HEPA filter unit is effective in reducing the concentration of airborne microorganisms in a DOR by about 70 percent. (U)

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INTRODUCTION

Cross infection in dental operating rooms (DOR's) is a subject of considerable conjecture, particularly when airborne transmission of disease is in question. The normal origin of airborne microorganisms is actions such as sneezing and coughing and movements that dislodge bacteria-bearing particles from skin and clothing, but DOR's contain various additional sources for the creation and dissemination of microbial aerosols. Investigators have shown that mechanical instruments (e.g., air turbine handpieces[1-6] and ultrasonic scalers[7]) are capable of increasing the microbial content of air. Pelleu[8] has found that dental unit water systems are also important sources of air contamination.

The airborne route of infection has been established as the mechanism for transmitting a number of diseases,[9] and droplet nuclei have been implicated as the primary mode of transmission.[10,11] Riley and O'Grady[11] have described infectious particles that remain in the air as being of two basic varieties, dustborne and droplet-nuclei borne. Dustborne particles are removed by sedimentation, but droplet nuclei less that 5 microns in size are so light they remain suspended for relatively long periods. High efficiency filters have been shown to remove from 90 to 99 percent of all particles in the 1- to 5-micron diameter range.[12] Whitfield[13] has shown that laminar air filtration systems containing prefilters and high efficiency filters maintain the quality of air throughout an enclosure at values equal to those produced by high efficiency filters themselves. Laminar flow filtration consists of sweeping a confined area with highly filtered air flowing along parallel lines at a constant rate. which requires installation of a laminar-flow filtration system covering one entire wall of a room. The cost of such a system would be prohibitive for the average DOR; however, individual blower-filter modules are relatively inexpensive, and it was interesting to speculate on the effectiveness of a floor-placed module in filtering out suspended microbial particles.

The purpose of this investigation was to evaluate the effectiveness of a single high-efficiency particulate air (HEPA) filter unit in reducing the number of viable particles in the air of DOR's under normal working conditions.

MATERIALS AND METHODS

Three DOR's with capacities of 1600, 1800, and 3240 cubic feet, respectively, were used in this study. The primary dental activity in the smallest DOR was cleaning teeth with an ultrasonic scaler; that in the other DOR's was operative dentistry.

The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

AIR FILTRATION.--A floor model blower-filter module* containing a HEPA (high efficiency particulate air) filter was used. This module filters approximately 800 cubic feet of air per minute (cfm) and conforms to Federal specifications for an efficiency of 99.97 percent or more on particles 0.3 micron in diameter and larger.[14] The module was placed on the floor against a wall 6 to 8 feet from the patient's mouth, with the filtered air outlet facing the dental working area and the air intake about 4 feet above the floor. The module was started 24 hours before the initial samplings for microbial content of filtered air were taken.

AIR SAMPLINGS.--Air samplings of 55 minutes' duration were taken four times a day (at 8 AM, 10:45 AM, 1 PM, and 3 PM) to measure concentrations of viable particles per cubic foot of air. Samplings were taken with 1-hour slit-type air samplers† with the slit width set at 0.152 mm and the airflow rate controlled at 1 cfm by a flowmeter.‡ The culture medium, which was contained in 150 by 25 mm disposable plastic Petri dishes,§ was prepared by layering 5 percent whole sheep blood in trypticase soy agar‖ over a previously poured layer of the same medium without blood. After sampling, all plates were incubated at 37°C for 24 hours. Colonies were then counted in reflected light. Each colony was assumed to represent a single viable particle in the air, and the microbial concentration was defined as the number of viable particles per cubic foot of air.

Samplings were taken in each DOR for 2 weeks without air filtration and then for 2 weeks with air filtration.

At the start of the study, two samplers were routinely used to compare counts at different locations. The orifices of both samplers were 2 to 3 feet above the floor; one positioned 1 foot from the patient's mouth and the other about 10 feet from the patient's mouth. No significant difference was noted between the counts at these positions; therefore, all further samplings were made at the latter position.

Since activities within the DOR's varied during the sampling day, the following three categories of activity were established for effective comparison and evaluation of results:

Category 1. None (no activity and no persons in the DOR).

Category 2. Normal (normal activity without a patient in the DOR).

Category 3. Dental procedures (activity including the performance of dental procedures on a patient).

A mean viable particle (VP) count was obtained by averaging all values obtained throughout the day; a mean peak viable particle (PVP) count was obtained by averaging values obtained during 5-minute peak recovery periods.

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*Model No. 43, Agnew-Higgins, Garden Grove, Calif.

†Reyniers sampler, Model FD-100, Reyniers and Son, Chicago, Ill.

‡Model 0800F, Gelman Instrument Co., Ann Arbor, Mich.

§Catalog No. 1013, Falcon Plastics, Los Angeles, Calif.

‖Baltimore Biological Laboratories, Inc., Baltimore, Md.

RESULTS

When the results of collecting airborne viable particles from two different positions in one DOR were compared (Table 1), the level of contamination 1 foot from the patient's mouth was generally the same as the level approximately 10 feet from the patient's mouth for all categories of activity. This was observed both with and without air filtration.

Table 1.--Airborne microbial concentration in a dental operating room

Activity	Number of Trials*	No Air Filtration: Position A† (VP/Ft^3)§	No Air Filtration: Position B‡ (VP/Ft^3)	Number of Trials	Air Filtration: Position A (VP/Ft^3)	Air Filtration: Position B (VP/Ft^3)
Dental procedures	26	7.8 ± 3.9‖	7.6 ± 3.1	14	2.2 ± 1.9	2.9 ± 1.9
Normal (no patient in room)	12	3.5 ± 2.4	4.6 ± 2.7	7	0.6 ± 0.6	1.6 ± 5.7
None (no persons in room)	7	0.9 ± 0.5	1.3 ± 0.8	5	0.1 ± 0.1	0.3 ± 0.2

*Each trial represents a dual sampling at positions A and B.
†Sampler orifice positioned 1 foot from patient's mouth.
‡Sampler orifice positioned 10 feet from patient's mouth.
§Viable particles per cubic foot of air.
‖Standard deviation.

The effects of air filtration on microbial concentrations in the air of all dental operatories tested were tabulated (Table 2). Reductions ranging from 47 to 99 percent were noted in all cases where air filtration was employed, irrespective of the type of activity in the room. Some samples collected during use of the ultrasonic scaler without air filtration revealed a shower of colonies (Fig 1) with momentary counts higher than 300 VP/ft^3. In all cases where high peak counts like these were recovered during ultrasonic scaling, over 90 percent of the bacteria were identified as alpha-hemolytic streptococci of the viridans group.

The effect of air filtration on peak microbial concentrations is given (Table 3 and Fig 2). Highest peak values were found where the ultrasonic scaler was used routinely. Air filtration produced reductions ranging from 56 to 84 percent in initial PVP counts produced by dental procedures, and from 67 to 97 percent in PVP counts remaining 10 to 20 minutes after dental procedures. On two isolated occasions, particle sizes were checked with a six-stage sampler,* which

*Andersen sampler, Model No. 0101, Andersen Samplers and Consulting Service, Provo, Utah.

Table 2.--Effect of air filtration on airborne microbial concentrations in dental operating rooms with different activities

Activity	Room Size (Ft^3)	No Air Filtration: Number of Trials	No Air Filtration: VP/Ft^3*	Air Filtration: Number of Trials	Air Filtration: VP/Ft^3	Decrease in Microbial Concentration (%)
Dental procedures	1600	15	21.0 ± 27.0†	22	2.2 ± 2.7	90
	1800	13	2.6 ± 1.2	13	0.7 ± 0.4	~~73~~ 77
	3240	26	7.6 ± 3.1	14	2.9 ± 1.9	~~62~~ 97
Normal (no patient in room)	1600	3	1.9 ± 0.5	3	1.0 ± 0.0	47
	1800	4	1.5 ± 0.3	4	0.6 ± 0.4	60
	3240	12	4.6 ± 2.7	7	1.6 ± 5.7	65
None (no persons in room)	1600	5	1.7 ± 0.8	3	0.8 ± 0.6	53
	1800	3	1.1 ± 0.1	3	0.1 ± 0.0	91
	3240	7	1.3 ± 0.8	5	0.3 ± 0.2	77

*Viable particles per cubic foot of air.
†Standard deviation.

Table 3.--Effect of air filtration on peak airborne microbial concentrations in dental operating rooms

Room Size (Ft^3)	Primary Activity	Time (Min)	No Air Filtration (VP/Ft^3)*	Air Filtration (VP/Ft^3)	Decrease in Microbial Concentration after Air Filtration (%)
1600	Routine Scaling	0	185.0	29.0	84.3
		10	101.0	2.8	97.2
		20	30.0	1.0	96.7
1800	Operative Dentistry	0	7.7	3.4	56.0
		10	4.1	0.7	82.9
		20	2.5	0.7	72.0
3240	Operative Dentistry	0	26.0	8.5	67.3
		10	11.0	3.6	67.2
		20	7.3	1.6	78.0

*Viable particles per cubic foot of air.

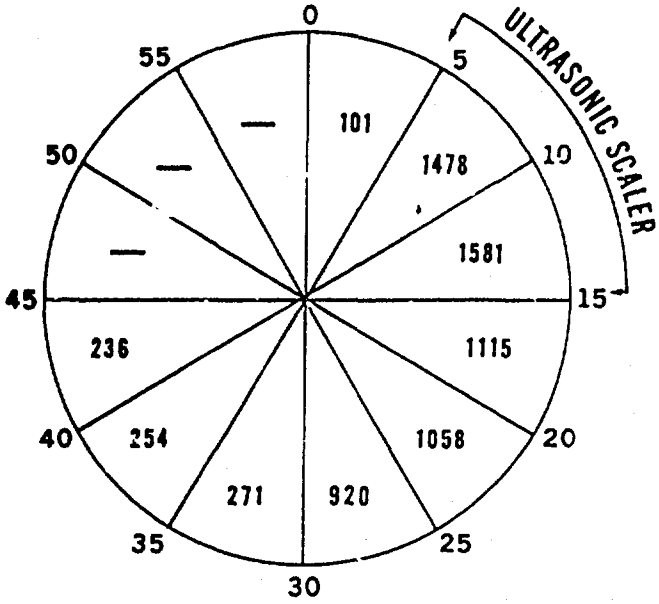

Fig. 1. Diagram of slit-type air sampler plate showing colonies collected in 5-minute periods following use of ultrasonic scaler. Numbers around periphery represent time in minutes. Flow rate = 1 ft^3/min.

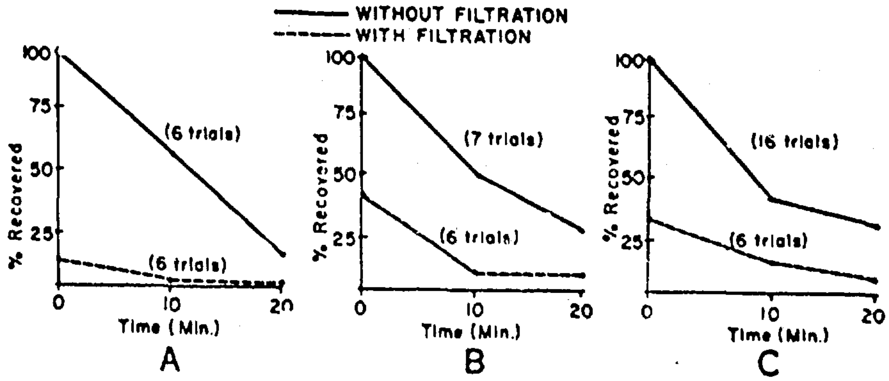

Fig. 2. Clearance rates of peak concentrations of viable particles in dental operating rooms with and without filtration of air. Peak values during periods of dental activity. A = 1600 $Ft.^3$ (100% = 185 ± 80). B = 1800 $Ft.^3$ (100% = 8 ± 4). C = 3240 $Ft.^3$ (100% = 26 ± 14).

revealed that over [illegible]0 percent of the viable particles recovered during peak counts were less than 1 micron in size.

The influence of room size on the efficiency of the 800-cfm HEPA filter module is shown in Table 4. No significant difference in effect was noted in two DOR's where operative dentistry was performed despite a difference in size of 1800 ft^3 versus 3240 ft^3.

Table 4.--Efficiency of HEPA filtration related to room size

Primary Activity	Room Capacity (Ft^3)	Effect of Air Filtration: Reduction in Viable Particles (%)	Effect of Air Filtration: Reduction in Peak Viable Particles (%)
Routine Scaling	1600	90	84
Operative Dentistry	1800	73	56
Operative Dentistry	3240	62	67
	Mean:	75	69

DISCUSSION

The HEPA filter was effective in reducing microbial levels in all cases regardless of the nature of activity in the DOR. A combined reduction of approximately 70 percent was noted for VP concentrations as well as PVP concentrations in the air. It is interesting to note that these results compared closely with those obtained in another study[15] made with the same filter module but under experimental conditions in which a static aerosol was employed.

Differences between the sizes of the rooms used in this study were not large enough to be a factor in determining the efficiency of the 800-cfm HEPA filter. However, the level of microbial contamination in the air may be a factor in calculating efficiency of reduction. Air filtration appeared to be more efficient in the DOR where the ultrasonic scaler was used and VP and PVP concentrations were highest. It has been reported[12] that filters have greater collecting efficiencies at higher velocities, particularly when particles are in high concentrations. This would indicate that even better results might be anticipated in DOR's having higher microbial concentrations than those in this study.

Mean peak counts of 185 VP/ft^3 of air in the DOR where the ultrasonic scaler was used were the highest obtained in this study. It is noted that the predominant bacterial strain recovered is an alpha-hemolytic streptococcus of the viridans group. This finding may mean that the ultrasonic scaler causes a release into the air of large numbers of these bacterial strains, which normally are associated with dental plaque. Further study is needed to clarify this relationship.

Although potentially pathogenic microorganisms have been recovered in the air of DOR's, no studies have proved or disproved a link between them and the occurrence of a disease. There is a need for a comprehensive study to define the relationship between air contamination and infection rates in dentistry. In the meantime, dental operatories, like other areas where patients are treated, should be managed in accord with the sanitary approach to the problem of cross infection; i.e., the cleaner the environment, including the air, the less will be the chance for cross infection. The filtering module tested in this study reduces microbial concentrations in the air of DOR's considerably. Other modules, with lower filtering efficiency ratings and with less capacity, are also available and the effectiveness of some of these is currently being tested. It has been established, however, that a single 800-cfm capacity HEPA filter module is effective in reducing the concentration of airborne microorganisms in a dental operating room by about 70 percent.

SUMMARY

A floor model blower-filter module, with a high-efficiency particulate air filter and a capacity of 800 cubic feet per minute, was tested for efficiency in reducing microbial concentrations in the air of 1600-, 1800-, and 3240-cubic-foot dental operating rooms under normal working conditions.

Samplings of microbial concentrations in the air of dental operating rooms, taken with a slit sampler, varied according to the amount and type of activity in a room, ranging from 3 to 185 viable particles per cubic foot.

Air filtration through the blower-filter module resulted in an average reduction of about 70 percent in the number of viable particles in the air.

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