

Microbial aerosols in general dental practice

A. M. Bennett,¹ M. R. Fulford,² J. T. Walker,³ D. J. Bradshaw,⁴ M. V. Martin,⁵ and P. D. Marsh,^{6,7}

Objective To measure the concentration of microbial aerosols in general dental practices and to use this information to carry out quantitative microbiological risk assessments.

Methodology Microbial air sampling was carried out continuously during 12 treatment sessions in 6 general dental practices in the South West of England.

Results The microbial aerosol concentration in treatment rooms was generally less than 10^3 colony forming units per cubic metre of air (cfu.m^{-3}). However, in 6 out of the 12 visits, at least one peak concentration with much higher numbers of bacteria was detected. The peak concentrations were associated with increased recoveries of presumptive oral streptococci suggesting these aerosols originated from the mouths of patients. These aerosol peaks dissipated within 30 minutes and no dissemination into waiting areas was detected. The peak concentrations were associated with mechanical scaling procedures (47% of procedures giving rise to a peak) and to a lesser extent by cavity preparation (11%). No aerosolised blood was detected.

Conclusions The data have been used to generate a framework for quantifying risk of exposure of staff to aerosolised microbial pathogens in general dental practice. For example, dentists and their assistants may have a slightly higher risk of exposure to *Mycobacterium tuberculosis* than the general public. The use of face seal masks that have been shown to protect against aerosolised micro-organisms may reduce this exposure.

The risk of aerosol transmission of pathogenic agents during dental treatment is unknown. Dentists use high-energy equipment, such as drills and scalers, in the presence of bodily fluids such as blood and saliva, and dental plaque. This combination has been shown to generate aerosols of oral micro-organisms, and blood.¹⁵ While the normal oral microflora of a patient contains high concentrations ($c 10^8 \text{.ml}^{-1}$) of ACDP (Advisory Committee on Dangerous Pathogens) hazard group 2 micro-organisms,^{7,9} their aerosolisation is not thought to pose a serious health risk. However, when patients harbour viruses, either blood-borne or respiratory, or respiratory bacterial pathogens such as *Mycobacterium tuberculosis*, aerosol generation may prove a significant health hazard to dentists and their assistants. If infective aerosols persist there may be some danger of exposure in the waiting area and for subsequent patients.

There is some evidence for greater prevalence of respiratory diseases^{2,3,14} and elevated antibody levels to *Legionella pneumophila*,¹⁸ in dental workers.

The majority of previous studies of microbial aerosols in dental surgeries have been carried out in a hospital setting. Most dental treatments are carried out in general dental practice. The objective of this project was to measure the concentration of oral micro-organisms and blood in the air of typical general dental surgeries. The data generated have been used to carry out a quantitative risk assessment of dental treatment on patients infected with blood-borne pathogens and *M. tuberculosis*.

Materials and methods

Selection of surgeries

Six general practices in the South West of England were selected for participation in the study. Each surgery was sampled during winter and during summer. Morning treatment sessions, from about 09.30 to 13.00, were chosen for air sampling to allow transport and assay of the samples within the same day. There were no restrictions on the number of patients (2–15) nor on the type of treatment they received. Dentists routinely used high volume aspirators and were supported by a dental nurse in 11 out of the 12 sessions.

Microbiological air samplers

The Casella slit sampler (Casella, London). This sampler operates by drawing air at $30 \text{ litres.min}^{-1}$ through a slit onto a rotating agar plate. The sampler was used continuously, for 2-minute periods, during treatment sessions. The sampler was placed within one metre of the patient's mouth, at bench height, opposite to the side the dentist was working. An additional Casella sampler was used to take background samples for 5-minute periods outside the treatment room every 30 minutes.

Andersen sampler.¹¹ This sampler was placed close to the foot of the dental chair within two metres of the patient's mouth. This sampler separates the microbial aerosol onto six different agar plates according to their particle size. The sampler was operated for 5-minute periods at a flow rate of $28 \text{ litres.min}^{-1}$ during procedures which were thought to have the potential to generate aerosols.

Microbiological media

The Andersen and Casella air samplers were operated with the following agar media, used alternatively:

- (i) Tryptone-Yeast extract-Cystine (TYC) agar⁴ was used for the enumeration of extracellular polysaccharide producing oral streptococci (identified presumptively by colony morphology and Gram staining).
- (ii) Columbia blood agar (Biomérieux) was used for the non-selective detection of total micro-organisms.

All plates were incubated anaerobically in an atmosphere of 10% H_2 , 10% CO_2 and 80% N_2 at 37°C for 7–14 days before colonies

¹Research Scientist, ³Research Scientist, ⁴Research Scientist, ⁶Programme Leader, CAMR, Porton Down, Salisbury SP4 0JG; ²General Dental Practitioner, Dental Practice, Town Street, Shepton Mallet, BA4 5BE; ⁵Senior Lecturer, Honorary Consultant Microbiologist, University Dental Hospital, Liverpool L69 3BX; ⁷Professor of Oral Microbiology, Leeds Dental Institute, Leeds LS2 9LU
Correspondence to: A. M. Bennett, Centre for Applied and Microbiology and Research, Salisbury, Wiltshire SP4 0JG
email: allan.bennett@camr.org.uk

REFEREED PAPER

Received 13.03.00; Accepted 13.07.00

© British Dental Journal 2000; 189: 664–667

were counted.

The IOM sampler (SKC, Blandford Forum). The Institute of Occupational Medicine (IOM) sampler consists of a sampling head, containing a filter cassette, designed to sample the human inhalable dose at a flow rate of 2 litres.min⁻¹ using a small sampling pump. The filters used were 25 mm diameter, 0.2 µm pore size, cellulose nitrate membrane filters (Whatman, Maidstone). The IOM sampling heads were clipped to the chest of the dentists in this study for the entire session. After sampling, the membrane filters were removed from the cassette using sterile forceps, placed into 2 ml of distilled water and vortex mixed for 1 minute prior to assay for blood. The samples were analysed for the presence of blood using Hemastix strips for urinalysis (Bayer, Newbury). This method was originally used to measure blood in dental aerosols by Miller.¹⁵ Samples were also plated out for detection of streptococci and total microorganisms on TYC and Columbia agar.

Results

Microbial aerosol levels

The normal microbial aerosol concentration during the treatment sessions was found to be ≤10³cfu.m⁻³. Extracellular polysaccharide (EPS) producing oral streptococci made up between 0 and 10% of the micro-organisms recovered from TYC plates. This reflects the background levels expected in small rooms containing five people (dentist, assistant, patient and two others). Similar levels were found in the samples taken outside the treatment rooms.

In 6 of the 12 treatment sessions monitored there were sudden increases in the concentrations of bacteria detected. These peaks were defined as an increase in colony counts on Columbia measured by the Casella slit sampler by at least three fold from background to at least 1.5 x 10³cfu.m⁻³. In the majority of instances this increase was duplicated by an increase in recoveries measured by the Casella sampler on TYC agar and measured by the Andersen sampler on Columbia to greater than 10³cfu.m⁻³. Since the increases in concentration found on Columbia agar were matched by separate samples taken onto TYC agar and by samples taken by a different sampling device it seems unlikely that these peaks arose by chance. A typical Casella result showing peaks from one of these sessions is shown in Figure 1a. The results from all the sampling visits are summarised in Table 1. The peaks associated with the blood agar plates were usually matched by increased recoveries on TYC. Presumptive oral streptococci (EPS-producers) made up over 50% of the colonies on TYC plates during peaks suggesting that some dental procedures gave an increased production of airborne orally-derived micro-organisms. In most instances, the bacterial numbers had returned to the normal background level after 10–30 minutes. No peaks were found on either visit to two of the surgeries (Fig. 1b). Blood was not detected in any of the personal air samples (detection limit 11µl.m⁻³). There was no evidence of spread of microbial contamination outside of the treatment room during the peak aerosol concentration periods.

The percentage of aerosol peaks associated with different dental procedures is shown in Figure 2. Eleven peaks were found during 23 scaling procedures, whereas, only 4 of 36 drilling episodes produced aerosols (Chi² test statistic 9.98, P = 0.001578). Therefore, it seems that microbial aerosol generation is often caused by scaling, although less than 50% of scaling procedures gave rise to aerosol peaks, implying additional factors may be involved. The data are analysed for each individual surgery in Table 2. The scalers used in Surgeries A, C and D were particularly prone to aerosol generation.

There was no definite relationship between the type of scaler and aerosol generation, with both sonic and ultrasonic scalers generating aerosols; 37.5% and 50% of ultrasonic and sonic scaling procedures, respectively, resulted in aerosol peaks. Air scalers seemed to

Table 1 Air sampling results from winter and summer visits

Surgery	Winter		Summer	
	Number of aerosol peaks	Maximum peak (cfu.m ³)	Number of aerosol peaks	Maximum peak (cfu.m ³)
A	1	6.9x10 ³	3	6.2x10 ³
B	1	8.7x10 ³	0	NA
C	0	NA	2	3.0x10 ³
D	3	6.3x10 ³	3	4.4x10 ³
E	0	NA	0	NA
F	0	NA	0	NA

NA – not applicable

be most associated with aerosol generation (72.7% of procedures gave peaks) compared with 42.8% with the commonest ultrasonic scaler. Similar levels of aerosol contamination in surgeries and waiting areas were found during winter and summer visits.

Risk assessments

A risk assessment was carried out by calculating the airborne levels of aerosolised saliva. This was determined by dividing the average salivary concentration of oral streptococci, obtained from Melville and Russell (1981),¹² by the peak aerosol concentration of oral streptococci found in this study. This figure was then used to calculate the potential aerosol levels of other pathogens from their known salivary or blood concentrations taken from the literature. The following assumptions have been made:

- The dentist and assistant are exposed to a peak aerosol concentration for 15 minutes and they have a breathing rate of one m³.hour⁻¹.
- Oral streptococci are as aerosol stable as the other pathogens.

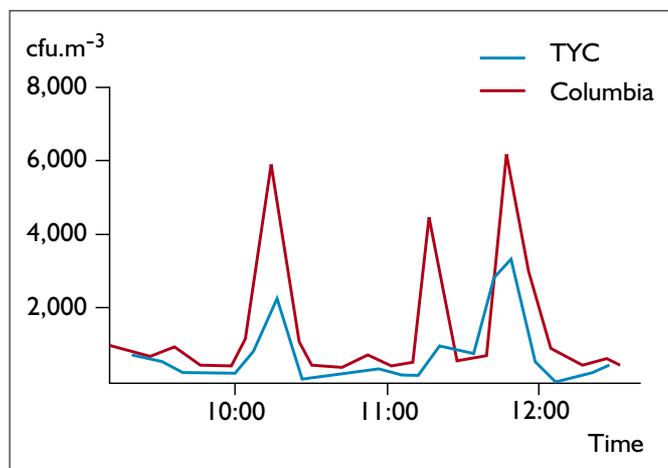


Fig. 1a. Casella air sampling results from surgery A — summer

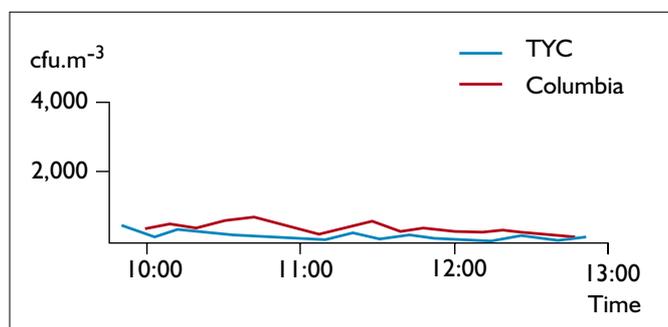


Fig. 1b. Casella air sampling results from surgery E — summer

Table 2 The relationship between aerosol peaks and dental procedures for the individual surgeries

Surgery	Drilling associated peaks Drilling episodes (%)	Scaling associated peaks Scaling episodes (%)
A*	1/8 (13)	3/3 (100)
B*	1/5 (20)	0/1 (0)
C†	0/4 (0)	2/2 (100)
D†	2/5 (40)	6/9 (67)
E*	0/7 (0)	0/4 (0)
F†	0/7 (0)	0/5 (0)

*Ultrasonic scalers

†Sonic air scalers

- The average concentration of streptococci in saliva is 6.7×10^7 cfu. ml⁻¹. A minimum concentration of 1.8×10^7 cfu.ml⁻¹ is used for the worst case scenario.
- The concentration of oral streptococci used for the mid-estimate was the highest airborne recovery of presumptive oral EPS-producing streptococci (3.7×10^3 cfu.m⁻³).
- The worst case estimate assumed that the highest concentration of colonies found on blood plates (8.7×10^3 cfu.m⁻³) consisted entirely of oral streptococci.

Using these figures we calculated that the dentist and assistant would inhale 0.014 µl of aerosolised saliva in a 15-minute peak exposure period. The worst case estimate is 0.12 µl in the same time interval. These figures have been used in the following risk assessments of exposure to dental patients who are infectious carriers of a) *Mycobacterium tuberculosis*, b) hepatitis B virus (HBV), and c) human immunodeficiency virus (HIV).

Untreated cases of tuberculosis have been shown to yield 7×10^4 cfu *M. tuberculosis* per ml saliva,²¹ giving a possible inhalation dose of 0.98 cfu *M. tuberculosis* and a worst case dose of 8.40 cfu *M. tuberculosis* to dental staff in our assessment. Since guinea pigs can be infected by one droplet nucleus containing *M. tuberculosis* this suggests a potential risk of aerosol infection with tuberculosis for dental personnel exposed to patients with tuberculosis. This risk may be reduced by use of personal protective equipment (Table 3).

An aerosol route of infection by blood-borne pathogens has been postulated;¹⁵ inhaled micro-organisms may enter the bloodstream via specific uptake mechanisms or through small abrasions in the respiratory tract. Since no aerosolised blood was detected by the IOM personal sampler (detection limit 11µl.m⁻³) the figures for aerosolised saliva were used, as for tuberculosis.

The infectious dose of HBV by inoculation has been reported as being as low as 10 picolitres of blood from patients with acute hepatitis B infection (10×10^{-9} ml, ref. 5). The risk assessment gives a mid-estimate inhalation dose of 1,400 infectious units by inoculation and the high estimate 12,000 infectious units by inoculation. However, it remains extremely unlikely that a viral particle will be deposited in an area of the respiratory tract that will allow it access to the bloodstream. Most dentists are vaccinated against HBV so they should not be at any significant risk from aerosol exposure to HBV. It seems extremely unlikely that any subsequent patients will be exposed to an infection risk as the peak aerosol levels were shown to drop to normal levels within 15 minutes.

HIV is found in lower numbers than HBV in the human body (eg a median concentration of 162 RNA copy numbers per ml from 25 samples of saliva from HIV positive individuals with a maximum recovery of 72,080 copy numbers).¹⁰ Using the mid- and worst case estimate for salivary air concentration with the median HIV concentration, an aerosol dose of HIV of 0.0023 and 0.019 copy numbers, respectively, is obtained. Even using the highest salivary concentration found using the main and the worst case estimate we get an aerosol dose of only 1.01 and 8.65 copy numbers. Even the

highest of these exposures are extremely unlikely to cause any risk of infection in exposed dental staff or patients although the minimum infective dose is not established.

Respiratory protection and safety glasses are commonly used to reduce the risk of aerosol exposure. Most dentists used a variety of surgical masks although in this study population some of them did not wear any mask (data not shown). The dental assistants were less likely to wear face masks. A study of the effectiveness of four surgical masks in preventing penetration by bacterial aerosols found that the penetration of aerosols through these masks varied from 72.6% to 2.2% of the bacterial spore challenge (Masks A and B).¹⁹ Another study found that if certified N95 respirators were challenged with bacterial spore aerosols the penetration was <0.5% (Mask C).¹⁶ The figures from the risk assessment for tuberculosis and HBV have been combined with mask performance data in Table 3. The use of a high performance N95 respirator could prevent exposure to hazardous concentrations of airborne pathogens. The correct use of a face seal mask with a validated standard of performance against microbial aerosols could greatly reduce any risk of exposure to pathogenic agents in the setting of general dental practices.

Discussion

The results of this sampling programme have shown that for long periods the expected normal background levels of microbial aerosols were found in most dental surgeries. However, on occasions, higher levels of oral micro-organisms were generated during particular dental procedures, especially during mechanical scaling. The aerosol peaks tended to decrease to the background levels within 10 and 30 minutes caused by rapid deposition of particles after aerosol generation at patient head height (approximately one metre from the ground). There appeared to be no difference between the aerosol levels recovered during the winter and summer sampling programme.

The peak levels found during dental procedures are over ten times higher than those reported by some authors.^{7,8} However these authors were sampling in ventilated rooms in dental hospitals for periods of between 20 minutes and 1 hour, which may have caused aerosol peaks to be missed. Our results are in good agreement with Larato *et al.* (1967) who used a similar air sampler over shorter 5-minute periods in a dental hospital treatment room.⁹

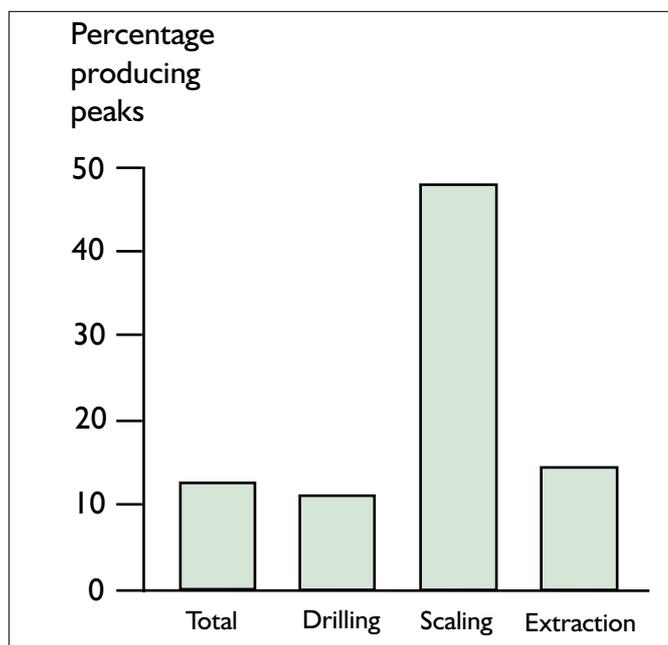


Fig. 2 Relationship between peak concentrations and dental procedures

Table 3 Effect of face masks on respiratory exposure to microbial aerosol of *M. tuberculosis* and HBV (based on efficiency data of Wake et al. 1997 and Quian et al. 1998)^{16,19}

	Potential respiratory exposure*			
	No Mask	Mask A	Mask B	Mask C
Mtb mid [†]	0.98	0.71	0.022	0.0049
Mtb upper [†]	8.40	6.10	0.19	0.042
HBV mid [‡]	1,400	1016	30.8	7.00
HBV upper [‡]	12,000	8,712	264	60.0

*If protective equipment is used correctly

[†]Dose is expressed in cfu inhaled during 15 minutes at a breathing rate of one cubic metre per hour

[‡]dose is expressed as infectious dose by inoculation inhaled during 15 minutes at a breathing rate of a cubic metre per hour

Mtb – *M. tuberculosis*

Masks are defined in the text

The personal exposures of dentists measured by the IOM personal sampler were generally low and few oral streptococci were recovered from the filters. Hardy organisms such as streptococci survive impaction upon filters.⁶ These low counts might be related to difficulties in ensuring the filters faced towards the patients mouth at all times during dental treatment. However, it may be that the aerosols produced during treatments are sprayed away from the dentists' bodies and are quickly mixed into the room air. This would explain the close agreement between the aerosol levels found by the Andersen and Casella samplers which were placed two metres from each other in our study. Thus the aerosol exposure of dentists and assistants may be of similar magnitude.

Oral streptococci are relevant indicators of salivary contamination of air. Williams *et al.* (1956) reported that streptococci made up only 3.1% of the total airborne microbial population in a survey of school classrooms, at a concentration of 109.5 cfu.m⁻³.²⁰ In the present study, however, some of the microbial air samples were made up of about 85% presumptive oral streptococci (EPS producing isolates) giving a peak concentration of 3.7 x 10³cfu.m⁻³, which is 34 times the average concentration found by Williams *et al.* (1956).²⁰ Reid *et al.* (1956) found a direct correlation between *Strep. salivarius* aerosol concentration and measles attack rate in school rooms.¹⁷ Our research suggests that the heightened exposure of dental professionals to salivary aerosols that contain opportunistic pathogens may lead to an increased incidence of respiratory disease in general dental practitioners and their assistants.

No aerosolised blood was detected in this study, which is in contrast to other work. Miller (1995) used a system in which powered dental instruments were used to aerosolise small volumes of blood in a simulation of scaling with gingival bleeding.¹⁵ Barnes *et al.* (1998) detected blood, visually and biochemically, on the tips of high volume evacuators (HVE) placed close to the scaler during sub-gingival scaling procedures.¹ However, this blood was not necessarily in aerosol form and may have consisted of large particles which would not normally be exhausted from the mouth.

The risk assessment carried out on infectious hazards in the dental treatment room shows that there may be a small risk to den-

tists of exposure to *M. tuberculosis* over and above the general risk associated with close exposure to infectious patients. This risk is small and could be greatly reduced by the correct use of personal protective equipment already used by some dentists in general practice.¹³ The risk to the subsequent patient in the treatment room will be almost entirely eliminated if there is a period of between 10 and 30 minutes between scaling and the entry of the next patient into the room.

This survey was supported by the NHS R&D Primary Dental Care R&D Programme. The authors would also like to express their thanks for the cheerful co-operation of the dentists, dental assistants and patients who took part in these studies.

- Barnes J B, Harrel S K, Rivera-Hidalgo F. Blood contamination of the aerosols produced by *in vivo* use of ultrasonic scalers. *J Periodontol* 1998; 69: 434-438.
- Basu M K, Browne R M, Potts A J C, Harrington J M. A survey of aerosol-related symptoms in dental hygienists. *J Soc Occup Med* 1988; 38: 23-25.
- Davies K, Herbert A-M, Westmoreland D, Bagg J. Seroepidemiological study of respiratory virus infections among dental surgeons. *Br Dent J* 1994; 176: 262-265.
- de Stoppelaar J, van Houte J, Backer-Dirks O. The relationship between extracellular polysaccharide-producing streptococci and smooth surface caries in 13-year-old children. *Caries Res* 1969; 3: 190-199.
- Feinman S, Berris B, Guha A *et al.* DNA:DNA hybridization method for the diagnosis of Hepatitis B infection. *J Virological Methods* 1984; 8: 199-206.
- Fine D, Mendieta C, Barnett M *et al.* Efficacy of preprocedural rinsing with an antiseptic in reducing viable bacteria in dental aerosols. *J Periodont* 1992; 63: 821-824.
- Grenier D. Quantitative analysis of bacterial aerosols in two different dental clinic environments. *Applied Environ Microb* 1995; 61: 3165-3168.
- Gross K B, Overman P R, Cobb C, Brockman S. Aerosol generation by two ultrasonic scalers and one sonic scaler. A comparative study. *J Dent Hygiene* 1992; 66: 314-318.
- Larato D, Ruskin P, Martin A. Effect of an ultrasonic scaler on bacterial counts in air. *J Periodontol* 1967; 38: 550-554.
- Liuzzi G, Chirianni A, Clementi M *et al.* Analysis of HIV-1 load in blood, semen and saliva: evidence for different viral compartments in a cross-sectional and longitudinal study. *AIDS* 1996; 10: F51-56.
- May, K R. Calibration of a modified Andersen bacterial aerosol sampler. *Applied Microbiol* 1964; 12: 37-43.
- Melville T, Russell C. The human oral flora. In *Microbiology for dental students*. pp. 299-309. London: Heinemann, 1981.
- Meredith S, Watson J, Citron K, Cockcroft A, Darbyshire J. Are healthcare workers in England and Wales at increased risk of tuberculosis? *Br Med J* 1996; 313: 522-525.
- Mikitka D, Mills S, Dazey S, Gabriel M. Tuberculosis infection in US air force dentists. *Am J Dent* 1995; 8: 33-36.
- Miller R L. Characteristics of blood-containing aerosols generated by common powered dental equipment. *Am Ind Hygiene Ass J* 1995; 56: 670-676.
- Quian Y, Willeke K, Grinshpun S A, Donnelly J, Coffey C C. Performance of N95 respirators: Filtration efficiency for airborne microbial and inert particles. *Am Ind Hygiene Ass J* 1998; 59: 128-132.
- Reid D, Lidwell O, Williams R. Counts of air-borne bacteria as indices of air hygiene. *J Hygiene* 1956; 54: 524-532.
- Reinthal F, Mascher F, Stunzer D. Serological examinations for antibodies against Legionella species in dental personnel. *J Dent Res* 1988; 67: 942-943.
- Wake D, Bowry A C, Crook B, Brown R C. Performance of respirator filters and surgical masks against bacterial aerosols. *J Aerosol Sci* 1997; 28: 1311-1329.
- Williams R, Lidwell O, Hirsch A. The bacterial flora of the air of occupied rooms. *J Hygiene* 1956; 54: 512-523.
- Yeager H, Lacy J, Smith L, LeMaistre C. Quantitative studies of mycobacterial populations in sputum and saliva. *Am Rev Respiratory Dis* 1967; 95: 998-1004.