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Efficacy of Face Masks in Preventing Inhalation of Airborne Contaminants

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Use of surgical face masks has been advocated to protect clinicians from inhalation of aerosols containing organic and inorganic particulates. This study examined the ability of a 22 μm tracer particle to bypass the filtering capability of face mask material by peripheral marginal leakage of inspired air. For two popularly used face masks taped to a facial moulage, recovery of the tracer particle by an in vitro system was very low. When the masks were placed in the manner in which the product is commonly worn, however, significantly higher numbers of particles were recovered. Passage of inspired air around the periphery of two types of face masks appears to circumvent the masks' ability to screen airborne contaminants.

Recent public and professional concern regarding communicable disease transmission has prompted the dental profession to evaluate the means by which both the patient and the clinician are protected from the risk of cross contamination. The use of face masks has been advocated by the ADA and the CDC to reduce the incidence of acute and chronic respiratory infections and for the prevention of inhalation of particulate matter.[1]

During dental procedures, large quantities of microorganisms and other contaminants are incorporated into the aerosols that are commonly generated by high speed handpieces using water spray coolants.[2–5] The aerosols contain soluble and insoluble particles of various sizes below 50 μm, potentially pathogenic microorganisms, and blood components.[4–7] Inhalation of pathogens of bacterial and viral origin places the clinician at risk for contraction of a spectrum of infections that includes relatively benign upper respiratory infections, flu and pneumonia, more serious conditions such as tuberculosis, and potentially lethal virulent viral diseases like meningitis.[8]

Particles larger than 50 μm generally behave in a ballistic fashion and are not incorporated into suspended aerosols. Particles of 20–50 μm, however, may be incorporated into aerosols; such particles are generally filtered by the nose during breathing. Inhalation of particulate matter in the 5–20 μm range results in deposition by inertial impaction in the bronchi and bronchioles. Thus, insoluble particles deposited in the tracheobronchial compartment are cleared by the mucociliary escalator and by macrophage phagocytosis.[9]

Particles in the 1–5 μm range are deeply penetrating, reaching the nonciliated alveoli and terminal bronchioles of the respiratory system.[10–14] Furthermore, they may remain suspended in the air, available for inhalation, for periods up to several hours.[3,8] Acute conditions or chronic states of pneumoconiosis may result from exposure to particulate matter, depending on the nature of the particle, the total load, and the duration of the exposure.[12,15–17]

Although surgical masks were introduced to screen bacteria from open surgical wounds, protection of the clinician has also become a legitimate function. Many studies have evaluated masks of various designs, construction, and materials over the years.[3,4,6] In vitro investigations of masks constructed of woven synthetic fibers have shown the mask fabric to be highly effective in preventing penetration by particles and bacteria, including 5 μ material.[18–21] Additional investigations have exam-

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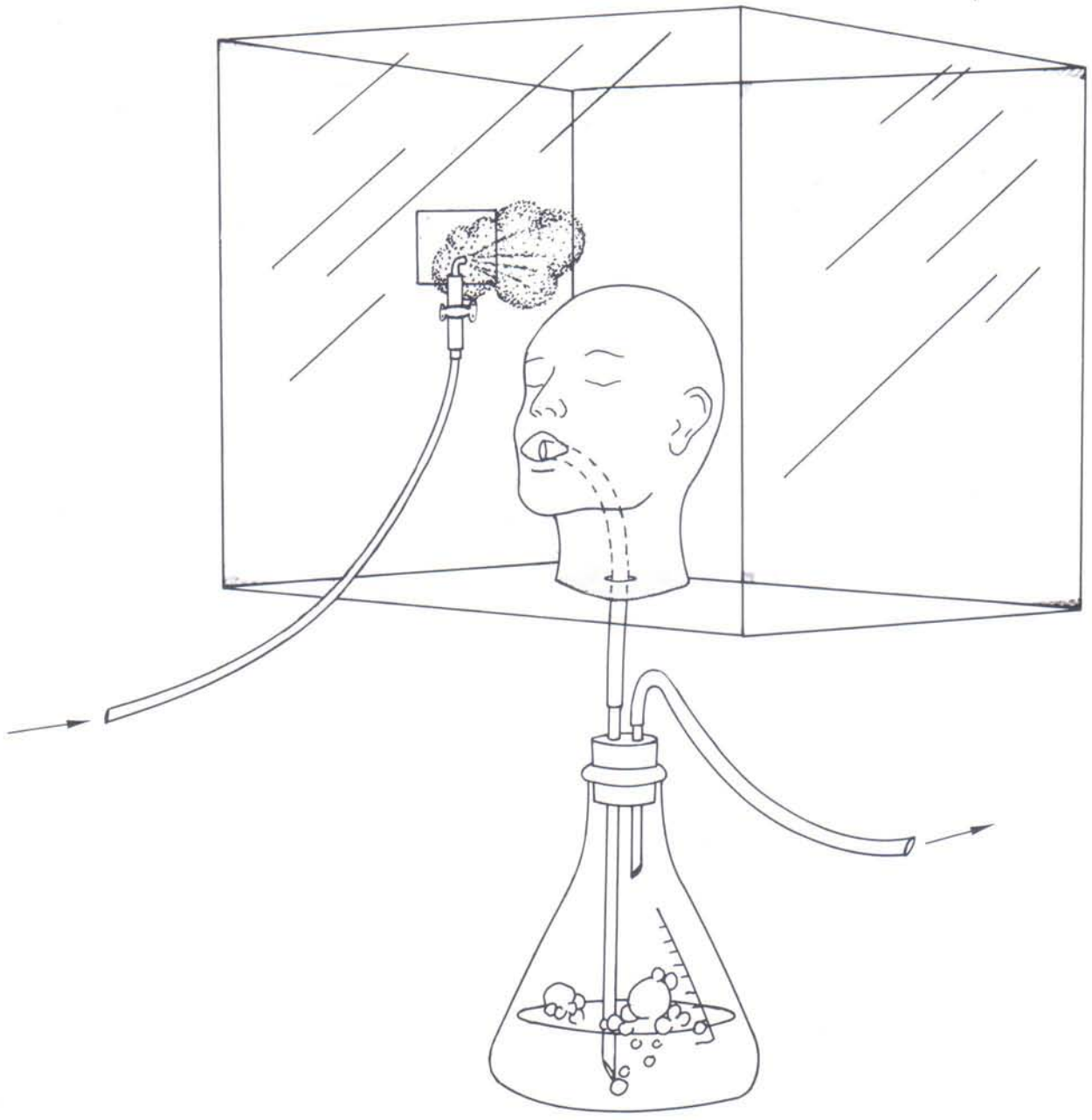

FIGURE 1. Inhalation chamber and recovery system. Capitis moulage is shown without mask.

ined the ability of masks to prevent the dissemination of bacteria from the clinician into the environment by use of controlled airflow chambers, Andersen impactor samplers and enumeration of colony forming units on supplemented agar plates.[5,22] Experimental trials utilizing human models have demonstrated significant passage of bacteria into the environment during the wearing of face masks.[6,23]

Although the material of new, popularly used masks is an effective barrier, it has been shown that airflow during expiration takes the path of least resistance resulting in marginal leakage around the periphery of the mask rather than air movement through the mask material.[24] In usage, such airflow patterns would force the mask to act as a baffle, deflecting the expired air with its microbial load rather than filtering it.[19] If the airflow during inhalation also bypasses the mask material due to marginal leakage, and if dental aerosols are suspended in the immediate environment, a potential exists for a reduced filtering efficiency of the mask, thus placing the wearer at risk for exposure to environmental contaminants. This investigation examined

the ability of a tracer particle to circumvent the filtering capability of two types of surgical face masks by airflow around the mask periphery during inhalation.

Materials and Methods

A plexiglas chamber 8 cubic feet in volume was constructed with a port for the introduction of a tracer particle, spores of *Lycopodium clavatum*. The spores are distinctive, brilliant yellow 22 μm spheres. Placement of the opening in the chamber was high and centered to facilitate test aerosol particle dispersion and suspension in the chamber. A plaster moulage of a stylized head was fabricated and placed centrally in the chamber. Fourteen millimeter diameter Tygon tubing led from the open mouth to a 2 L collection flask below the chamber containing 1 L of deionized water. The tubing terminated well below the surface of the water. A 0.3 ml aliquot of Tween 80 was added to the water to facilitate spore suspension. A vacuum source providing a flow of 50 L of air per minute was connected to the flask by a separate glass stem high above the water level (Fig. 1). This experimental method mimicked inhalation only. The set-up was designed to simulate moderately high leakage.

Standardization of the spore load was accomplished by introduction of air entrained *Lycopodium* spores into the operating system, recovery of spores in the collection flask, and enumeration of multiple 1 ml standardized samples from the flask by a model FZ Coulter counter. Generation of a five-second pulse yielded 7.98 million spores (SD = 0.725 million). A background count was obtained by filtering air alone through the collection flask.

This system was used to assess in vitro marginal leakage during inspiration for two popular, commonly used face masks (Glass-free surgical mask #47123-010, American Hospital Supply Corp. and 3M Aseptex 1800 molded surgical mask, 3M Company). For group 1, a woven synthetic fiber tie-on mask was placed on the moulage in a conventional manner. The same mask was taped to the moulage at the periphery to eliminate marginal leakage in group 2. Group 3 consisted of molded, preformed surgical masks held in place by an elastic retention band. The molded mask was taped to the moulage to constitute group 4. Group 5 served as a control, without placement of a face mask.

The face masks were evaluated for filtration efficiency of the mask fabric and for marginal leakage. Eight experimental trials were conducted for each test and control procedure. Each of the masks was placed on the moulage in the manner in which the product is commonly worn. The vacuum system was engaged and a total of five one-second pulses of *Lycopodium* spores was introduced into the chamber at one-minute intervals. Five minutes of simulated inhalation followed. For each trial, the collection flask was multiply sampled with a 1 ml pipette and the specimens were analyzed by a Coulter counter. The background count was subtracted from each sample count. Between trials each mask was removed and a new mask was fitted to the moulage. The same procedure was carried out for each experimental group and the control group. Data were analyzed using a one factor ANOVA and Newman-Keuls Multiple Comparison Procedure.

Table 1. Number and Percentage of Spores Recovered for Each Treatment Group

Group	Mean*	SD	% Recovered
1. American Hosp. conventionally worn $n = 8$	9.64	(1.12)	24.20
2. American Hosp. taped $n = 8$	0.08	(0.11)	0.00
3. 3M conventionally worn $n = 8$	12.34	(4.93)	30.90
4. 3M taped $n = 8$	0.15	(0.24)	0.00
5. Control $n = 8$	9.81	(0.82)	24.60

* Means reported in millions of spores.

Results

Table 1 summarizes the means and percentages of spores recovered from each of the experimental groups. The data illustrate a significant percentage of passage of the total spore load to the recovery system with both of the conventionally worn masks (groups 1 and 3) and the control group (group 5). Masks taped to the facial moulage (groups 2 and 4) allowed a very low percent of passage. This difference was significant for both types ($P < 0.05$). However, there was no significant difference between the two types of mask when worn either conventionally or taped to the moulage.

Discussion

Aerosols produced during dental procedures have been identified as a significant factor in upper respiratory infections, transmission of tuberculosis,

FIGURE 2. Marginal seal integrity of face mask varies with individual facial structure.

transfer of pathogens, and production of pneumoconiosis. The first-line of defense in controlling the dissemination of aerosols into the dental environment is the high velocity suction system. To be effective, the suction tip must be placed near the handpiece head to ensure an airflow gradient into the suction apparatus.

Surgical face masks could be capable of providing an important mechanism of minimizing cross contamination due to airborne contaminants. In vitro studies have demonstrated the effectiveness of the newer mask materials of woven synthetic fibers in preventing penetration of small particles.[18–21] This investigation supports the effectiveness of modern mask materials in preventing the passage of particulates in the 22 μm range. When masks from groups 2 and 4 were taped to the facial moulage, allowing air passage only through the material, very few spores were recovered; compared to the control group, this was highly significant.

Several studies have alluded to possible marginal leakage of masks allowing air with its contaminant load to bypass the mask material.[8,24] Passage of air around the periphery of a face mask during inspiration, and especially during sighing, appears subjectively apparent to clinicians. Indeed, surgeons often use adhesive tape to secure masks to the skin over the bridge of their nose to prevent fogging of their eyeglasses that results from air movement across the glass during exhalation. Observations in our clinic reveal gaps in the marginal seal of clinicians' face masks varying with individual facial structure (Fig. 2). Some are purposely worn loosely to counteract the impedence of the fabric experienced during breathing.

This investigation supports the contention that marginal leakage can be a significant factor in the filtration efficiency of surgical face masks. Masks worn in a conventional manner (groups 1 and 3) allowed as many spores to reach the recovery system as the control group (group 5). In addition, there was no statistically significant difference between the masks, although the percent recovered was slightly higher for group 3. This strongly suggests a very low efficiency for face masks worn in a conventional manner. The pronounced marginal leakage may be related to the inability of the mask to adapt to the irregularities of the face and to impedence of airflow by the mask fabric leading to airflow around the mask periphery.

Examination of the results shows groups 1 and 3, masks worn in a conventional manner, had an increased mean recovery of spores over the control group. However, it is probably not sound to suggest that wearing a face mask slightly increases the percent of spores recovered. The increased count is more likely due to variations in the exact number of spores delivered into the chamber and to sampling errors. It should be noted that great care was taken to uniformly disperse recovered spores by agitation of the flask immediately prior to sampling and by the addition of Tween 80. Multiple samples were taken (10 per recovery flask) and enumerated to extrapolate to the total number recovered. However, only small (1 ml) samples were taken for processing by the Coulter counter and it is conceivable that they were not perfectly representative of the total number of spores in the recovery flask.

To aid in facial adaptation, some masks incorporate special features in their design. Manual ties allow the practitioner to fit the mask tightly, improving the adaptation. Masks with malleable metal bands at the nose area allow special attention to adaptation in this area. Results of this investigation suggest the further need for the development of a tissue adhesive surface along the mask periphery to minimize airflow around the edges of the mask. Such a sealant would direct airflow through the mask fabric ensuring filtration of contaminants and increasing the margin of safety to the clinician and the operating field in an era of heightened awareness of the transmission of disease.

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