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Potential Risk Factors for Aerosol Transmission in the Dental Office and Strategies for Prevention and Control

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Abstract: Objective: Dental offices, due to the special characteristics of diagnostic and treatment operations and airborne diseases, are exposed to relatively closed environments with high concentrations of aerosols for a long period of time, and there is a possibility of disease transmission through aerosols. This paper introduces and analyzes the sources, distribution, hazards, and prevention and control strategies of oral bioaerosols, hoping to provide some references for reducing the hazards of oral aerosols and optimizing errors and omissions in dental treatment. Materials and Methods: By reviewing and summarizing the way of generating oral aerosols, the factors affecting their distribution in the past two decades, and reviewing the related literature, we explored the hazards of oral aerosols to the organism and the reasonable preventive and control measures. Results: Aerosol in dental clinic can spread through many forms, such as saliva of patients, water vapor splashing from dental high-speed mobile phone operation, etc., which increases the risk of infection between doctors and patients. Conclusion: A large amount of aerosols will be generated in the process of oral diagnosis and treatment, and the pathogens contaminating the air can directly lead to respiratory tract infections, and can also indirectly infect human beings through contaminated medical devices. The risk of aerosol transmission can be reduced through good scientific protection, standardized operation, rinsing and disinfection, and the use of isolation and strong suction equipment.

Keywords: Dental Office, Bioaerosols, Prevention

1. Introduction

Aerosols are liquid and solid particles with a diameter of 50 μm or less suspended in the air. It is composed of various organic particles. There are many sources of bacterial aerosols inside and outside the oral clinic. Dental practice is a dynamic process and a large number of aerosol contaminants can be generated during dental practice. In the dental office, patients coughing, sneezing, doctors and patients communication will produce a large number of droplets, oral treatment will also produce a large number of droplets and aerosols, droplets can be attached to nearby objects in a short period of time, the diameter of less than 50μm droplets will quickly dehydrated into droplet nuclei suspended in the air around the operating table for a long time, while the aerosols will also be mixed with droplet nuclei in the air for virus and bacterial transmission, becoming a source of infection for healthcare workers and patients, and posing a potential nosocomial infection risk to dental healthcare workers and patients if not removed in a timely manner [1]. Bacteria and other contaminants in the air of dental clinics can spread a variety of infectious diseases to medical personnels and patients. High-speed handpieces, triple-use guns, ultrasonic shock instruments etc, which are often used in daily dental operations, produce large quantities of aerosol particles during operation, especially when dental cutting and restoration and ultrasonic equipment and high-speed handpieces are required, the amount of droplet and aerosol generation and transmission range will increase rapidly, posing a great challenge to the treatment and care of dental clinics. It can be seen that improving air quality during dental treatment, reducing aerosol generation, preventing cross-infection, and safeguarding the safety of patients and medical personnels are important measures to prevent and reduce hospital-acquired infections effectively [2]. This paper reviews the domestic and international literature on oral aerosols, and aerosols generated during dental treatment and their transmission risk and prevention, to provide reference for dental personnel to do a good job of protection to avoid cross-infection in dental treatment operations.

2. Sources of Contamination of Aerosols in the Dental Office

2.1. Contamination of Dental Instruments

Routine cleaning and sterilization procedures should eliminate contamination of all dental instruments, but the current ones used at patient sites cannot be effectively sterilized. Most mechanical instruments used in dental procedures produce aerosols from the site where the instruments are used [3], most notably from dental handpieces, ultrasonic scalers, air polishers, and air abrasive devices. Each of these instruments removes material from the surgical site, which becomes atomized by instrument rotation, ultrasonic vibration, or the combined action of water jets and compressed air to produce large amounts of aerosols. Aerosols in the dental environment have also been associated with the use of low-speed handpieces, air/water syringes, patient coughing, and intraoral radiography [4]. Because aerosols can remain suspended in the air and travel farther than droplets, they may cause contamination and spread disease at a distance, even after the infected person has left the vicinity. The source of microbial contamination in dental aerosols has been shown to be primarily from dental rinses, with a low or undetectable contribution from salivary microbial sources.

2.2. Contamination from the Operation of High-Speed Equipment on Dental Complex Treatment Tables

Strong aerosol and droplet nuclei have been shown to be generated during the use of ultrasonic scaling machines and high-speed heads without rubber barriers. The collection and testing of aerosols and droplets generated during different oral treatment processes: ultrasonic scaling, high-speed turbine handpiece grinding, and restorative prep dentistry, showed that 47% of the treatment processes during 23 cases of ultrasonic scaling exceeded the colonization count; 11% of the treatment processes during 36 cases of high-speed turbine handpiece grinding exceeded the colonization count, which indicates that ultrasonic scaling is the large number of aerosols and droplets generated of the main cause [5]. Bacterial contamination of the patient and operator's face after ultrasonic scaling was found to be more than 30-fold higher by adenosine triphosphate (ATP) bioluminescence assay [6]. Aerosol contamination caused by the use of high-speed turbines during cavity preparation and grinding and polishing of composite resin fillings is even more severe than that of ultrasonic instruments.

3. Factors Affecting Aerosol Transmission

3.1. The Distribution Range of Oral Bioaerosol

As early as 1998, Discacciati added dye to the water supply of the dental chair to observe the splash during the operation and showed that the dental chair, the patient and the health care provider, and the operating table with sterilized instruments were within the splash range (0.609 m) from the patient [3]. In a closed office, aerosol contamination can extend to almost the entire office, including non-operating areas [7, 8]. Some scholars have also sampled the surfaces of objects in the consultation room and showed that all 120 specimens exceeded the total bacterial count, with a gradual decrease in contamination with increasing distance [9].

In 2012, a researcher placed agar plates at different distances directly in front of the patient and to the left and right side of the head during ultrasonic scaling, and the experimental results again confirmed that the degree of contamination gradually decreased with increasing distance [8]. In 2013, Nejatidanesh et al. observed visible splash spots on the physician's mask after 144 periodontal and restorative treatments, and the results showed that the most contaminated areas were around the nose and around the inner canthus [10]. In 2015, Umar et al. sampled various surfaces in the dental office and the bacterial culture results The locations with the highest positive rates were the lamp handle, the doctor's pen, and the tip of the suction tube, followed by oral equipment and devices.

3.2. Particle Diameter and Dispersal Distance

The splash operation of oral treatment can produce spatter, droplets and aerosols, and the dispersal distance is from near to far, and the settling speed decreases in turn. The droplets are usually larger than 100 μm in size, visible to the naked eye, have sufficient mass and kinetic energy, and have ballistic characteristics to splash onto the operator's eyes, mouth, nasal mucosa, mouthpiece, goggles, forehead, right arm, etc. [11, 12]. Droplet particle size between the droplet and droplet nucleus, droplets of large particle size in the air after rapid descent does not exist for a long time, generally after a few seconds in the range of 1 m settlement, droplets below 100 μm can evaporate and can be converted into smaller particle size droplet nucleus [13]. Droplet nuclei are usually less than 5 μm in size and can be suspended in the air for a long time and are considered as aerosol particles. Droplet nuclei can attach pathogenic microorganisms and their activity can decay with time. Aerosols are dispersed systems of solid or liquid particles suspended in a gaseous medium for long periods of time, with particle sizes ranging from 0.001 μm to 100 μm, which are not visible to the naked eye and can drift with air currents [14-16]. The human body inhales more than 1 billion particles per day, and the effect of these particles on the human body depends on the particle properties, deposition location and concentration [17]. Droplets with particle size greater than 50 μm are hardly inhaled by the human body, and particles with particle size greater than 10 μm are almost all deposited in the nose and throat; most particles smaller than 3 μm can enter the human lower respiratory tract and are at risk of causing allergic diseases and other serious illnesses [17]. In addition to particle size, indoor ventilation rate, air temperature and humidity, airflow pattern, initial velocity, and particle composition all influence the retention and dispersal of particles in suspension in the air [18].

3.3. Aerosol Contamination from Different Oral Operations

The amount of aerosols generated by different dental practices varies. Evaluated in terms of microbial concentration, the most severe aerosol contamination was observed during ultrasonic scaling using plate culture method bacterial colony (Colony forming units, CFU) detection, followed by pneumatic high-speed dental handpiece tooth preparation, polishing and water-air gun application [19]. The differences in microbiological sample collection and culture methods make it difficult to compare the results between different studies. Up to now, the main method for analyzing microbial species of aerosols in the dental office is the bacterial culture method, and the microorganisms that can be captured and cultured in the study are only a small fraction of the air, the limitation of this method is that it can only detect specific species of bacteria and cannot detect viruses, fungi, or parasites, and more technical means of detection and identification methods are still needed to verify that other microbial aerosol species in the dental office, the source, transmissibility, pathogenicity, etc.

The natural deposition method generally only collects particles >8 μm in diameter and requires static sampling. The air sampler method can simulate the human lower respiratory tract to capture aerosol particles with a particle size of 0.65-4.70 μm. Both sampling media are selected according to different culture objects with different media [20]. The requirement for the average air colony count in the dental office in China's Hospital Disinfection Hygiene Standards is ≤ 4.0 CFU/dish (plate exposure time of 5 min), and the international requirements for air quality are generally static, lacking standards for the air colony count during dental treatment, and the dynamic monitoring index of microbial aerosols during dental treatment deserves clinical attention and further exploration [5].

Rautemaa et al. reported that the mean colony count of air colonization culture in the office using high-speed equipment was 823 CFU/(m^2·h), while the results for the group without rotary and ultrasonic instruments were 598 CFU/(m^2·h) and 35 CFU/(m^2·h) for the group without operation [4]. Harrel et al. showed that the highest amount of aerosol was produced during the use of ultrasonic instruments and high-speed equipment was the second highest [21]. Ultrasonic scaling operation is more likely to produce a large number of inhaled micro-particle aerosols and droplets due to the high-speed vibration of the working head, and one study showed that after 2 h of ultrasonic scaling operation, the bacterial content in the air rose 4.3 times in a single dental chair office; 1 h after the end compared with the end of scaling, the number of bacterial colonies in the air fell 39% in a single dental chair office, which was 1.9 times higher than before the scaling operation, and the aerosols produced by ultrasonic scaling operation Aerosols can spread up to 1 m horizontally and 0.5 m vertically [22, 23]. It has also been found that aerosol contamination due to high-speed instruments is more severe than that due to ultrasonic equipment [24]. Although the experimental results obtained by different researchers varied widely, similar conclusions were reached: the highest levels of airborne colonies in the consultation room were found when high-speed and ultrasound equipment were used.

4. Health Hazards of Aerosols in Dental Consultation

Many dental treatment operations are accompanied by serious spatter and aerosol contamination. Dental triple-use guns, dental polishing brushes and sandblasting operations produce a large amount of spatter and aerosols, in which aerosols of about 0.3 μm are suspended indoors for up to 6 h [25]. In practice, the closer to the working site, the more serious the spatter and aerosol contamination, in order, is the patient's face, the health care provider's face, the dental chair fixture, the spittoon, and the treatment tray [26, 27]. Unlike aerosols resulting from tracheal intubation and respiratory microscopy, the vast majority of the water in dental aerosols does not originate from patient body fluids, so the concentration of pathogenic microorganisms carried within them, if any, is substantially lower than that produced by body fluids, and the risk of cross-contamination is lower than most people think [21].

The magnitude of the hazard of aerosols in the dental office is usually estimated based on the type and amount of microorganisms present in the aerosol. During ultrasonic scaling, a large amount of water vapor mist is produced due to the cavitation effect of ultrasound, which mixes with the patient's exhaled gas, saliva and blood to form aerosols, and the long operation time of ultrasonic scaling leads to the persistence of aerosols in a larger area of the office, a fact that has been considered a major concern for infection prevention and control and occupational safety protection in hospitals. Experts proposed that the scope of aerosol transmission in the dental office is not limited to the dental treatment table, but may extend to the entire office, including non-operating areas [28]. A large number of literature reports found that the increase of aerosol content in the office was significantly higher in oral cleaning using ultrasound equipment for treatment operations than in other treatment operations, with the highest bacterial aerosol content [29]. Li, Jing et al. also confirmed by using adenosine triphosphate bioluminescence assay that bacterial contamination of the patient and operator's face could be substantially increased by more than 30 times after ultrasonic scaling [30]. Harrel et al. also found that ultrasonic scaling caused a variety of bacteria and other microorganisms to diffuse in the office air as bioaerosols through ultrasonic atomization [26].

Some of the diseases known to be transmitted by droplets or aerosols are pneumonic plague, tuberculosis, influenza, Legionnaires' disease, and severe acute respiratory syndrome. Since health care workers have a high risk of acquiring pathogenic microorganisms through prolonged exposure to biological aerosols in the consultation room, it is inevitable that aerosols carrying pathogenic microorganisms will be dispersed in the air through dental cleaning operations once the patients themselves originally carry pathogenic microorganisms, exposing health care workers and the next patient working in this environment to potentially dangerous aerosols that may cause infection, therefore oral Treatment operations for reasonable protection is very necessary.

5. Prevention and Control of Aerosol Transmission in the Dental Office

Since the outbreak of the novel coronavirus pneumonia epidemic, the problem of aerosol transmission in the dental office has received widespread attention at home and abroad. The aerosol and droplet air pollution generated in the process of oral diagnosis and treatment has seriously threatened the health of health care workers and patients. Dental medical personnel should do a good job of scientific protection, wear all kinds of protective equipment correctly; standardize the operation, rinse and disinfect the patient's mouth before treatment, and use rubber barriers, strong suction equipment and other equipment that can reduce the diffusion of aerosols in the air during the dental treatment operation [1]; strengthen the usual hygienic cleaning of the treatment room, strictly ensure the neatness of the dental treatment table, and use a violet light to disinfect the air in the consultation room, so as to reduce the risk of aerosol transmission.

5.1. Strengthen Personnel Protection

5.1.1. Guarantee Patient Safety

The vast majority of dental consultations can be performed on an elective basis. Dental providers should clearly state in all patient communication media, such as posters in waiting areas, appointment slips, and online platforms, that they request that visits to be postponed when patients have fever and acute respiratory symptoms. This is the most important, yet most overlooked, respiratory disease precaution. In addition, waiting patients should wear masks, and there is evidence that patients wearing surgical masks can substantially limit the range of their droplet and disease-causing aerosol dispersal. A clinical trial in patients with pulmonary cystic fibrosis showed that without a mask, P. aeruginosa-containing aerosols could be detected 2 m away in 19 of 25 patients (76%) with cough, but only in 2 cases (8%) if the patient wore a medical surgical mask ($P<0.001$) [31].

5.1.2. Standardize Medical and Nursing Operations

When performing routine dental consultations, personal protective equipment for standard precautions for healthcare workers include medical surgical masks, face screens, disposable gloves, and barrier gowns; additional precautions should be taken in case of potential aerosol transmission [32]. Because of the risk of both liquid spray and aerosol contamination in dental operations, masks are required to have both high bacterial and particulate barrier capacity, as well as protection against penetration of body fluids. Intact, keratinized skin is well protected against viral attack. However, the conjunctiva can be infected by droplets, and although the risk is low, it is still recommended that health care workers wear a face screen for any operation where there is a risk of fluid splashing. Medical staff may wear protective gowns or reusable plain work clothes. Isolation gowns are worn when performing any invasive procedure that may result in bleeding, such as surgical gowns. Depending on the risk of cross-contamination, disposable waterproof barrier gowns or aprons may also be available. Standard prevention and control generally does not require full-coverage protective clothing.

5.2. Prevent Aerosol Transmission at the Source

5.2.1. Reduce Aerosol Production

Any aerosol-generating operation should be performed at the lowest possible power. In particular, ultrasound treatment should strive to perform clean scraping under conditions that do not produce significant water mist [33]. Sandblasting is highly susceptible to microscopic dust aerosols and a rubber sleeve with negative pressure suction should be used to wrap the sandblasting tip, which can substantially reduce aerosol production [34]. Another idea is to reduce the microbial load in aerosols, for example, by requiring patients to rinse with 0.12% chlorhexidine solution for more than 1 min prior to oral consultation [35]. One study found that the use of chlorhexidine gargle for 30 s before oral consultation could decrease the Staphylococcus aureus and Streptococcus pyogenes in the patient's mouth by more than 90%. By reducing the bacterial content in the patient's mouth and thus reducing the bacterial content within the aerosol produced during the operation; the rubber barrier isolates saliva and reduces the spread and transmission of microorganisms in saliva, thus reducing the production of bacterial aerosol. High-speed turbine handpieces are difficult to reduce the amount of aerosol production, but they can be used simultaneously with an anti-retraction handpiece, which serves to keep the dental chair clean with water and isolate the affected teeth with a rubber barrier [33].

5.2.2. Accelerating Aerosol Removal

Regular window ventilation is one of the effective methods to reduce the infectious aerosol content in the dental office; static air disinfection such as fixed ultraviolet light irradiation is often used for the irradiation disinfection of the air within the office. However, dynamic air purification is still needed when large amounts of infectious aerosols are generated during the treatment process. Studies have confirmed that the use of strong suction devices such as central suction during dental procedures can reduce bacterial levels in dental office aerosols. Any aerosol manipulation should be accompanied by high-flux suction for rapid aerosol removal [36], for which it is important to popularize and reinforce the four-handed dental practice. Diffused aerosols can be suspended for at least 30 min to 2 h in poorly ventilated dental offices, so it is necessary to accelerate aerosol dilution by increasing room ventilation or installing air purification systems in the office [36]. Air purification systems can significantly reduce the risk of infectious aerosols during operations such as cavity preparation, ultrasonic biopsy, and tooth extraction.

Chemical and physical methods of air disinfection can be used when ventilation is not available [37]. Air sterilizers with physical factors are used as the first choice and can be used in occupied conditions. However, UV lamp irradiation must not be used in occupied conditions, as it can cause some damage to humans, such as the occurrence of electrophthalmia and dermatitis. Ozone will remain after disinfection by conventional UV lamps, so personnel should not be allowed to enter until after ventilation. Installing germicidal UVC (254 nm) lamps indoors can effectively kill pathogenic microorganisms, especially Mycobacterium tuberculosis. This wavelength of UVC has minimal impact on human health, does not produce ozone, and can be used in occupied environments [38]. Air sterilizers with chemical factors are only used in unoccupied situations and also require ventilation after use. Air cleaning technology is generally used to clean operating rooms or special ward areas, but the construction costs are high. It is difficult to spread on a large scale.

6. Conclusion

It is particularly important to reduce aerosol contamination in dental surgery because aerosols and splashes generated during dental surgery have the potential to spread contamination to others and pose a health risk to others. In this paper, the sources, distribution, hazards and prevention and control strategies of oral bioaerosols are described, hoping to provide some references for reducing the hazards of oral bioaerosols and optimizing the errors and omissions in dental treatment.

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