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LITERATURE REVIEW

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Air management techniques in dental office in post COVID era: A Literature Review

Técnicas de gerenciamento de ar em consultório odontológico na era pós COVID

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ABSTRACT

The neoteric coronavirus outburst has jeopardised the health care system globally. As a result, practising dentistry has severe constraints due to production of aerosols and splatter in a large quantity. Air management gains foremost importance in reducing the transmission of SARS-COV-2 in a dental operatory. A variety of air filtration techniques have been put forth to optimize the air quality by removing the pollutants and pathogens. Amidst the blowing wave of information accessible online and on social media, it is puzzling to identify dependable research data and guidance to equip the operatory to minimize the risk of disease by aerosol, droplet and contact transmission. This paper presents comprehensive review on the different air purification technologies, their mechanism and utility in reducing viral load with the aim of providing information in regards to setting up a dental operatory with reduced risk of disease transmission in the post COVID-19 era.

KEYWORDS

COVID 19; Air management; HEPA filter; Air purifiers.

RESUMO

A explosão neotérica de coronavírus colocou em risco o sistema de saúde global. Como um dos resultados, a prática odontológica passou a ter restrições severas devido à sua grande produção de aerossóis e respingos. O gerenciamento de ar ganhou uma importância ainda maior na redução da transmissão do SARS-COV-2 em um procedimento odontológico. Uma variedade de técnicas de filtração de ar tem sido colocada para otimizar a qualidade do ar através da remoção de poluentes e patógenos. Em meio à onda de informações disponíveis online e na mídia social, é difícil identificar dados de pesquisas confiáveis e orientações para equipar os operadores a minimizarem os riscos de doenças transmissíveis por aerossóis, gotículas e contato. Este artigo apresenta uma compreensível revisão das diferentes tecnologias de purificação de ar, seus mecanismos e utilidades na redução da carga viral com o objetivo de prover informação quanto à prática odontológica com redução de riscos de transmissão de doenças na era pós COVID-19.

PALAVRAS-CHAVE

COVID 19; Gerenciamento de ar; Filtro HEPA; Purificadores de ar.

INTRODUCTION

The neoteric coronavirus outburst, well popularised as COVID-19 or novel corona virus pneumonia, has attained a pandemic state. The illness occurs due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. Rampant spread of this disease has jeopardised the health care system globally. Appropriate care during treatment is imperative for the prevention of spread of the disease. The dental procedures have high probability to spread the disease easily into the masses. The dental clinics are highly contaminated with microbiological air pollutants. High-speed rotary and ultrasonic based devices release a tremendous amount of aerosols or splatter of water, bacteria, viruses, exudates, and dental materials, contaminating the surrounding [2].

Recently, a study stated that the viral load of SARS-COV-2 is high in saliva and it is a component of aerosol, dentists are at an increased risk of getting infected [3]. So, countries witnessing COVID-19 disease have temporarily ceased elective dental treatment [4]. Dental professionals perceived a need to lessen routine dental procedures fearing the transmission of COVID-19 amongst the patients and the operators. However, limiting the dental procedures does not suffice the purpose in the long run. Amidst the blowing wave of information accessible online and on social media, it is puzzling to identify dependable research data and guidance to equip the operator to minimize the risk of disease by aerosol, droplet and contact transmission.

This article focuses on certain propositions that may help in improving air management protocol and protect the operator from the virus while carrying out routine dental procedures.

Air management techniques are categorized into two types of criteria (Table 1):

1. Quantitative;
2. Qualitative.

Quantitative criteria

Air flow and air changes per hour

Laminar flow pattern occurs when the flow of air is smooth exhibiting a parabolic velocity profile. Several studies have focused on the effect of laminar flow with microbial contamination of air and observed that it reduces airborne microbial burden under clinical conditions by 90% [5,6]. The same conclusion was drawn in a

Table 1 - Classification of air management techniques

QUANTITATIVE MANAGEMENT	QUALITATIVE MANAGEMENT (Air Purification and Disinfection)
1. Laminar air flow	1. Ion based air purifier-
2. Clear extraoral barrier	A. Anion based purifier
3. Controlled Air pressure Handpiece	· Negative air ion generator
4. High vacuum evacuators and extraoral suction	· Soft x-ray beam - Electron release
	B. Plasma based purifier
	· Hydroxyl ions release
	· Hydroxyl and hydroperoxyl ion release
	2. Photon based Air Purification
	· UVGI method
	· Photocatalytic method
	3. Filter based Air Purification
	· Carbon filter
	· HEPA filter
	· Electrostatic Precipitation based filter
	4. Gas based Air Disinfectant
	· Ozone
	5. Aerosol based Air Disinfection
	· Fumigation and fogging

review of WHO research on global guidelines in preventing surgical site infection [7].

Clear extraoral barrier

Plexiglass, is a transparent acrylic sheet recommended by CDC to shield against the droplets formed after coughing or sneezing [5]. A plexiglass sheet with a stand or in a form of box can be placed in such a way that it acts as a barrier in between the patient and the operator, and thus diverting aerosol and splatter [8].

Controlled air pressure handpiece

The compressed air of high-speed air turbine is directed at the irrigant site and generates dental aerosol or splatter in ample amount. Electrically driven dental handpieces have brought upheaval in dentistry [9]. The electric motor operates from 20 rpm to 200,000 rpm. On basis of the speed variations attained with motor connections, an individual handpiece helps in high speed (restorative and endodontic access) and low speed techniques (oral prophylaxis, surgical, and preclinical) at fixed torque. Its 'chip air' technique creates a mist at the terminal end of the hand piece rather than splatter [10]. The commonly used surgical air turbine has a 45° angled head which redirects the compressed air in direction opposite to the irrigant resulting in reduced splatter. The use of these handpieces with few limitation, amidst the COVID-19 outbreak may reduce generation of aerosols in absence of air jet on the irrigant [11,12].

High vacuum evacuators (hve) and extraoral suction

Aerosols and splatter created by dental procedures hold saliva, blood, and pathogens. This increases the chances of transmission of common cold and influenza viruses, herpes viruses, severe acute respiratory syndrome (SARS), and tuberculosis [13,14]. High vacuum evacuators and extraoral suction aim not only at water management but also at aerosol reduction to prevent disease transmission [15]. The extraoral suction, HVE fitted with HEPA filters and UV light disinfect the aerosol containing air evacuated from the oral cavity. They have a wide bore enabling elimination of more air in less course of time, which decreases the bioaerosols up to 98% [16-18]. On considering practice and protection point of view, saliva ejector renders it insufficient in minimizing aerosols in contrast to extraoral suction [19,20].

Qualitative criteria (Air Purification and Disinfection)

Ion generator:

Negative air ion generators

Air ionizers generate corona of negatively charged ions around the electrode supplied high voltage of current. The action of these ionizers is dependent on superoxide and activated oxygen species generation [21]. The conflicting results are found on its efficacy against bacteria and viruses [22]. However, negative ions undoubtedly effective for particulate materials and it varies with particle size, concentration and ventilation [23]. These ions bind to the suspended dirt or pollutants, rendering them heavy to settle onto the surfaces without altering the total microbial load [2]. Wiping the surfaces with disinfectant still remains mandatory to remove the settlement on its surfaces [24].

Soft x ray beam

In soft x-ray beam air purifier systems, the high speed electron stream is released into the chamber filled with air which directly attacks the cellular macromolecules (nucleotides and ribonucleotides) along with oxidative decomposition of the viral and bacterial surface membrane, ultimately destroying them [25]. The dose of high speed electron beam having lower penetrability and higher dose than gamma radiation has comparable efficacy at shorter exposure time [26]. The high speed electron beam at a dose of 0.4 KGy causes 4 log inactivation of bacteriophage MS2 in liquid medium [27]. A similar kind of mechanism is adopted in Electron streamer discharge technology and has demonstrated destruction of viral fragments effectively [28].

Hydroxyl ion release

The high voltage current is applied to discharge plasma from alternating electrode. Balanced shower positive hydrogen and negative oxygen ions are generated from atmospheric water and oxygen. These ions agglutinate with the surface of fine particles allergens and airborne pathogens. The hydrogen and oxygen ions conjugate together at the protein receptors of pathogen to form hydroxyl radical (OH). These radicals absorb hydrogen from the surface receptors which inactivates its bonding to the human cells [29,30]. The Plasma cluster technology works on a similar principle.

Hydroxyl and hydroperoxyl radical release

In this technique, the hydrogen and oxygen ions are released from plasma and together they give rise to hydroperoxyl and hydroxyl radicals. They envelop the airborne pathogens, including viruses and react with hydrogen ions of protein components of the cell membrane, destroying it to exterminate the pathogens forming water vapour as byproduct [31]. Junho et al. found that bipolar ions together are more effective than unipolar ions against viruses [32]. Also an experiment conducted in Kitasato Medical Center with a similar technology popularised as S-plasma ionizer showed elimination of up to 99.6% of viruses within 20 minutes [31].

Hydroxyl radicals and electron release

In Nanoe technology, high voltage current is applied to water which produce nano-sized, water wrapped micro particulate material composed of hydroxyl radicals encircled with electrons possessing antiviral activity [33] However, no research has been published and its efficacy yet to be explored.

Photon based air purification

Uvgi filter

The Ultraviolet Germicidal Irradiation (UVGI), with the wavelength of 190-254 nm

causes photodimerization of DNA and RNA of infectious agents resulting into cell damage [34]. These units are fixed in the operatory where the light is amplified and directed in surrounding by anodized aluminium reflectors. In a study, UV-C (254nm) was used to inactivate influenza A virus in aerosols and is an effective tool to reduce the spread of airborne mediated bacterial and viral diseases [35]. Studies have concluded that 7-241 joules/m^2 of dose exposure causes inactivation of various coronaviridae species [36,37]. Efficacy of UV-C sterilization is highly dependent on distance from the object. Doubling the distance reduces the potency to $1/4^{th}$ [38]. A typical 40-watt UVC tube source has sufficient radiation up to 6 feet to kill pathogens. This dose dependent mechanism may form ozone in the air so special glass filters with the UV spectrum steriliser addressing the concern of ozone formation [39,40]. The upper room airway disinfection luminaries disinfect the air during the procedure and UV stations are indicated for post-operative air sterilization. Measures should also be exercised to have adequate shadow-less exposure of UV light in the operatory, avoiding its exposure over photosensitive dental materials and humans.

Photocatalytic air purification

In photocatalytic air purification, UV excitation energy is generated after UV light is absorbed by titanium dioxide mesh. This excitation starts an oxidation-reduction (REDOX) reaction which produces superoxide radicals and strong oxidizing hydroxyl radical [41-43] that efficiently causes degeneration of pathogens leading to significant reduction of microorganism to 4 to 5 log [44]. However, titanium oxide with graphite releases carbon dioxide, which is a matter of concern [45].

Filter air purification

Activated charcoal filters

A special treatment of charcoal with oxygen increases the porosity of charcoal for improving its adsorptive property. These filters allow removal of volatile organic compounds, gases, particulate pollutants and unpleasant odour from the air by the principle of adsorption. However, they are less effective in removing pathogenic flora [46].

High-efficiency particulate air system

High-efficiency particulate air system (HEPA), are intended to filter at least 99.97% of dust, pollen, fungi, bacteria, viruses and airborne particulate material [47,48]. These filters appear to form a pleated fibre meshwork and are available in different grades from 10-17; depending upon their filtration rate and particle size. Out of these, 13 and 14 are considered as medical grade filters and have the retention percentage of 0.05 and 0.005 respectively for 0.1um particles per litre of air [49]. Medical grade HEPA-13,14 available in the market have a pore size of 0.3um and still trap corona viruses sized 0.125um to 0.06um by virtue of its entrapment mechanism. Diffusion of small particles like corona viridae occurs as they move through Brownian motion and end up hitting the fibres and getting stuck in the filter [42]. Air-purifying systems consisting of HEPA filters entrap particulate material but their disposal doesn't occur. Therefore, HEPA systems are generally fitted with ultraviolet light for its disinfection and viruses [50,51]. Ionic and electrostatic room air purifiers alone offer a very limited advantage in comparison to HEPA [52]. Thus, use of HEPA filters are trending for reaping clinical benefits [53].

The air turnover or air flow is measured as the air changes per hour (ACH) [6]. The value of ACH is calculated by dividing the volume of air in the operative theatre per hour (m^3/hr) with the volume of operating theatre [54]. Recent CDC guidelines suggest that ACH in the patient waiting should be 6, 12 in radiographic section and 15 in procedure room [55,56].

Electrostatic precipitation

Electrostatic precipitation works on the principle of corona discharge dependent on high input voltage. The system consists of two oppositely charged terminals between which the air flows. Through the negative electrode the polluted air is passed, rendering a negative charge to the contents. At positive terminal these negatively charged particulate material gets attracted and decontaminated air is filtered out [57]. In certain viruses like influenza, the lipoprotein cell membrane may also get eliminated on increasing current [58]. This mechanism facilitates exceptional possibilities for swift and easy elimination of virus from air and offers potential to identify and avert airborne transmission of viruses at lower velocity of air [58,59].

Gas based air disinfectant

Ozone generators

Ozone is a known oxidizing agent which releases reactive hydroxyl and peroxides radicals for its antiviral and antibacterial effect [60-62]. Sharma et al. in their study evaluated the efficiency of portable ozone generating device on inactivation of micro-organisms present in air and concluded that ozone can disinfect air and is a viable option for purifying air in community and hospital setups [63,64]. However, its effect on viruses demands more research. Also, at higher concentrations, ozone is potentially hazardous to health. The maximum acceptable level of ozone according to FDA per 21 CFR is 801.415 Thus, use of ozone generators in dental operatory is still controversial [65,66].

Fumigation and fogging

The varieties of fumigants available are formaldehyde with potassium permanganate, methyl bromide, hydrogen peroxide vapour and chlorine dioxide. Among these, formaldehyde is categorized as carcinogenic in nature and methyl bromide is avoided due to its ozone depletion action. The chlorine dioxide gas is effective against wide range of organisms [67]. Hydrogen peroxide (11%) with sliver nitrate (0.01%), popularized as Ecoshield is an effective, odourless agent with exposure time of 60 to 120 minutes making it comfortable for both patient and operator [68-70]. The area of the room and the number of equipment present in the room determine the time required for the disinfection. Practising fumigation in between the patients is a viable, effective and affordable option to control disease transmission. However, recently WHO has put forth new guidelines which suggest that fumigation and fogging does not substitute the need of wiping and cleaning the surfaces with disinfectant soaked cloth [24].

According to literature, UV light air purification has highest efficacy in reducing microbial load, followed by photocatalytic and plasma air purification respectively [71] (Table 2). However, UV radiation does not eliminate VOCs and pollutants from the air. This is effectively done by photocatalysis and plasma air purification technology [71]. But these techniques generate ozone and reactive radicals which necessitate its use with caution [72,73]. The enforcement of hydroxyl ions in various methods of air purification is vital against pathogens without aerosol. Hydroxyl ions with water in aerosol lead to the formation of hydronium and hydroxide ions which are found ineffective against aerosolised viruses [74]. Though, it should be noted that, these conclusions have been drawn from the current plethora of available literature and detailed evidence based analysis is required to substantiate the mentioned hypothesis.

Table 2 - Comparison of commercially available air purifiers

TECHNIQUE	ACTION	BACTERIA	VIRUS	AEROSOLISED MICRO-ORGANISMS
Negative ion generator	Superoxide and activated oxygen species generation	Not effective	Not effective	Not effective
Soft X-ray beam	High speed electron beam generation	Effective	Effective	Highly effective
Plasma based purifiers	Hydroxyl radical generation	Effective	Not obvious	Not obvious
	Hydroperoxyl and hydroxyl radical generation	Effective	Effective	Effective
Ultraviolet radiation	Ultraviolet germicidal irradiation	Highly effective	Highly effective	Effective
Electrostatic precipitation	Filtration of charged particles	Effective	Effective	Effective
Photocatalytic air purifying	REDOX reaction	Effective	Effective	Effective
Ozone generators	Reactive hydroxyl and peroxide generation	Effective	Not obvious	Not obvious

CONCLUSION

The dentist should be vigilant in selecting HEPA filter having effective filtration of 0.02um to 0.002um particulate material with added disinfection using fumigant or UV light will be a valuable tool for purifying the aerosol in dental office. Ionic and plasma-based purifiers have potent ability to inactivate the virus in a non-aerosolized state. The high-speed electron beam has an effective viricidal action against the aerosolised viruses. The use of Ozone, UV light and fumigation is proved to be effective in minimizing airborne infection. The judicious combination of multiple techniques concentrating on management of aerosol should be employed for safety of clinicians, auxiliaries and patients. Clinicians should also be aware of new regulations issued by their country's organizations before conducting any clinical procedure.

Author Contributions

NR: designed the review of literature. PVD, JM: drafted, edited and designed the manuscript. SB, NT: read and approved the final manuscript.

Conflict of interest

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