EVALUATING THE SPREAD OF AEROSOLS DURING CROWN PREPARATION: AN IN-VITRO STUDY

Farah El Meski
DDS, Gulf Medical University, 2018

Submitted to the Hamdan Bin Mohammed College of Dental Medicine
Mohammed Bin Rashid University of Medicine and Health Sciences
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Prosthodontics
2022

ABSTRACT

Evaluating the Spread of Aerosols During Crown Preparation: An In-Vitro Study

Farah El Meski

Supervisors: Dr Moosa Abuzayda, Prof Keyvan Moharamzadeh,

Dr Fatemeh Amir Rad

Background: The severe acute respiratory syndrome (SARS-CoV-2 or COVID-19) brought in an unanticipated dire situation and affected dental practice significantly. Due to the nature of profession, suspension of treatment was imperative as transmission was obscure. Patients did not display evident symptoms and therefore the threat between the dental team and patients was collective. There was a lack of apparent adherence to public health protocols which led to an astronomical number of cases, prolonged period of isolation, oral care neglect and finally decrease in quality of life. However, the current challenging situation ensured better approach and management of patients to optimize standards of care through understanding transmission, reducing spread and enhancing all modalities of treatment. The aim of this study was to explore and evaluate aerosol generation and spread by developing an established laboratory dependent approach strictly simulating prosthodontic aerosol generating procedures.

Materials and method: Restorative crown preparation on the upper right central incisor (#11) and upper right first molar (#16) was performed on a dental manikin in a simulated laboratory. Citric acid (10%) was injected into the waterline and litmus paper was used to demarcate the contaminated regions in the surrounding (30cm distance), the dentist's face-shield and chest and the simulated assistant's chest. The chromatic color change (blue to red) was analyzed through Fiji-ImageJ software to evaluate the color intensity (pixels) of aerosol generation.

Results: Contamination was detected at each allocated site. The maximum contaminated mean(SD) surface area was seen at 30cm behind the manikin's head for both tooth #11 and #16, 157.64(±0.68) pixels and 122.49(±2.89) respectively. Very low contamination levels were detected at the operator's face-shield for both tooth #11 and #16, 73.35(±0.78) and 65.14(±1.25) respectively. Reduced aerosol splatter was detected as contamination decreased with use of extra oral suction, demonstrating positive results. EOS resulted an average percentage decrease of 20.6% and 19.2% respectively with highest percentage decrease at the operator's chest.

Conclusions: Aerosol generating procedures such as restorative crown preparation impose high risk of exposure, and with the basis of our findings, mitigation options such as the extraoral suction and personal protective equipment support in reducing spread and chance of transmission.

DEDICATION

I dedicate this dissertation to my father, my mother and my sister for their profound love, faith and support throughout my journey. A special thank you to my parents for igniting passion, instilling a love for learning and for teaching me to have a dream. They have paved the route to my achievements and for that, I am eternally grateful.

And lastly, above all to Allah (Almighty God) for granting me health, grace and the power of mind. Thank you for being a pillar of strength and bestowing such an opportunity for me to share with my loved ones.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization

Name:

Signature:

ACKNOWLEDGEMENTS

A debt of gratitude owed to my respected supervisors, Dr Moosa Abuzayda, Dr Fatemeh Amir Rad and Professor Keyvan Moharamzadeh for their mentorship, their guidance and continuous faith throughout this project. I am grateful to have had the opportunity to pursue yet another milestone in my career along their side.

I am proud to acknowledge my university, Mohammed Bin Rashid University of Medicine and Health Sciences for the warm support and determination granted during my journey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

A pneumonic virus of unprecedented origin claimed us collectively towards the end of 2019, where it was termed as “Novel Corona Virus Disease (COVID-19)” by the World Health Organization (WHO) by January 2020. The unknown etiology of the disease challenged all medical domains and spread beyond control, ultimately declared as a global pandemic and public health emergency of great scope. The pandemic has also highlighted some of the major gaps in dental research and the need for new relevant knowledge to manage the current crisis and minimize the impact of such outbreaks on dentistry in the future (Barabari and Moharamzadeh, 2020).

Dentistry was noted a high-risk occupation in the prime midst of the pandemic, therefore it is essential to understand common routes of transmission to grasp the significance of reducing the aerosols generated. On 15 March 2020, the New York Times published an article entitled “The Workers Who Face the Greatest Coronavirus Risk”, describing the level of risk dentists are exposed to compared to nurses and general physicians. The outbreak has constrained dentists to only manage emergency treatments confined to aerosol/droplet free treatments. This took a drastic impactful measure on the economic and psychological sector of the dental team. Meanwhile, the government adopted policies and imposed quarantine to contain the rapid growth of the virus to “flatten the curve” and attain protection and safety of both citizens and healthcare providers. The lack of evidence-based dentistry has exposed the disparity in awareness of personal protective equipment (PPE) and other cross infection control measures. The uncertainty regarding the most appropriate PPE is uncharacteristic for the dental team. Each country worldwide was compelled to develop the most appropriate policies accordingly to cope with COVID-19 and its novel manifestation. The pandemic established no protocols, infecting people of all ages, ethnicities and climate. Daily dentistry was not disposed and what seemed conventional has plainly led to the new normal.

The vastly infectious respiratory disease was found to cause substantial threat in dentistry as it derived from aerosol generation lingering in the air and infiltrating respiratory passages. As stated by Murray and Slack (1957), the dental office served as a reservoir with contaminated surfaces, dental instruments and direct exposure with body fluids of an infected patient. The dynamics of transmission took place throughout our daily routine thus making it more difficult to contain. Unlike the severe acute respiratory syndrome coronavirus 1, SARS-CoV-2 has shown a greater tendency for rapid human-to-human transmission, with an R0 (reproduction ratio) varying between 1.4 and 6.5, and an incubation period ranging from 2 to 14 days, with an average of 7 days (Park et al., 2020). Coronavirus derives its name from its complex infrastructure. It is composed of an envelope (E), membrane (M), nucleocapsid (N) and spike (S) proteins. The spike protein forms large protrusions from the virus surface, giving the appearance of a crown. The rapid progression of COVID-19 is stimulated through the activation of RAAS (Renin-Angiotensin-Aldosterone System) and the disturbance of the ACE2 (Angiotensin-converting enzyme 2) respectively. It mediates multiple organ injury and is highly noted in patients with concomitant diseases such as diabetes mellitus, cardiovascular disorders and hypertension (Beyerstedt et al., 2021) which is evident in the geriatric patients presented in prosthodontic emergencies.

1.1 The novelty within novelty

The novelty of this pandemic offers scarce literature. The aim is to provide additional insight into the issue we are currently tackling. This study should aid in identifying what is known and remains unexplored. The virus's existing pool of knowledge is shallow with conflicted and/or inconclusive evidence; therefore, the novelty of our investigation will significantly support and highlight the scope for further research.

Past work such as Ionescu et al. (2020) focused mainly on the microbiological evaluation of bacterial contamination from aerosols and splatter following dental procedures, by counting aerobic bacteria colonies deposited into agar plates positioned at various locations. Miller et al. (1971) and Hackney et al. (1998) conducted similar experimental setups with biological traces such as streptococci to detect the pattern of aerosol contamination. However, there is insufficient literature to support the difference in viral and bacterial activity due to their contrast chemical and physical properties. A Cochrane review by Jefferson et al. (2010) established that only two of the 59 published studies stated that there is no conclusion specific to influenza viruses. There is also insufficient data on the distribution of aerosols and splatter for the most frequently prosthodontic procedures, such as the high speed handpieces in crown preparation. Only numbered experiments such as the one conducted by Vernon et al. (2021) reviewed aerosol generation for full crown preparation in the upper left lateral incisor indicating that the anterior region poses the highest risk of exposure. Therefore, this study is to acknowledge a direct method to map the pattern of splatter/aerosol during aerosol generating procedures.

1.2 Prosthodontics throughout COVID-19

The community shared between COVID-19 and prosthodontic dentistry is geriatric patients. Granted that prosthodontic treatments do not deal customarily with emergencies but a prosthodontist is required to manage urgent affected quality of life care. Emergencies that justify appointments with a prosthodontist include urgent provisionalisation, broken or fractured dentures which might lead to immediate or temporary denture fabrication and/or adjustment. This age group covers mostly procedures that require aerosol generation such as contaminated acrylic debris from denture repairing, temporary or final crown fabrication and multiple clinical visits. Though mortality is scant, the spreading potential is high (Zhou et al., 2020). Prosthodontists are exposed to copious saliva, blood and aerosol generation through pre-prosthetic procedures, implant placements and exposed to indirect contact with dental laboratories and dental technicians through impressions and dental casts. Prosthodontists exclusively rely on multiple visits where several members in a chain are involved, starting with the dentist, assistant, laboratory team and back to the dentist again. Consequently, this increases the susceptibility of infection casting a unique challenge to establish precaution and safety. Prosthodontic treatments need to be tailored to adapt to the current mishap. Aerosol generating instruments serve as a dominant source of viral transmission and therefore, versatile parameters need to be established to counter the spread. Whether it is taking dental impressions, pouring models, fabricating, finishing, polishing and delivering prosthesis, every checkpoint should be taken with extra caution. Teledentistry serves as an elemental advantage in managing prosthodontic emergencies.

1.3 Fixed Prosthodontics

Aerosol generating procedures in fixed prosthodontics are predominantly elective. Procedures such as fabrication of crowns, bridges, onlays, inlays, post and cores, veneers and full mouth rehabilitation should be performed with great conformity. Debonding of the resin-bonded fixed partial denture framework (Thoma et al., 2017) is the most commonly reported failure seen and often poses as an urgent request for an appointment. Ideally, if the patient has no present symptoms then this can be managed after the pandemic. However, it is within urgent significance to advice the patient to use self-application desensitizing agents in cases of hypersensitivity for the exposed abutment tooth. Conventional fixed bridges impose a bigger challenge as there could be numerous reasons for dislodgement such as incorrect cementation or poor retention. Action should be taken depending on whether the patient is symptomatic or not. Pain or soft tissue impingement of the fixed bridges can place geriatric patients in further distress and lead to malnutrition, anxiety, insomnia or social lifestyle disturbance affecting overall quality of life (Bloom et al., 2017). The prosthesis should be attended to if the patient is in distress and informed on available treatment options and temporization.

Papi et al. (2017) concluded that digital methods reduce human contact at multiple steps thereby decreasing risk of transmission of virus, saves time and improves efficacy. Chair side protocol should also be retained at a minimum. Auxiliary measures such as rubber dam and extra oral suction are recommended throughout procedures that demand high concentration of saliva and blood contaminants exposure (Chen et al., 2020). Clinical and radiographic examination are fundamental means for diagnosing dental problems however most emergencies in prosthodontics could be solved with either sectional panoramic imaging or extra oral bitewings to minimalize contact and avoid aerosol exposure through saliva. However, if intraoral imaging was necessary, it is essential to use double barrier protection. Extra oral readjustment of prosthesis is recommended whilst using disposable burs and full protection in disposable PPE. The laboratory serves as a transit of cross contamination; therefore, any impressions must be carefully disinfected and sealed in a pouch. CAD/CAM restorations and digital workflow is favored to reduce salivary splatter and contact.

1.4 Dental impressions

There is broad bio-contact for prosthodontists particularly with dental impressions. Dental impressions are an adjunct to infection transmission. Disposable trays are recommended opposed to stock trays where autoclaving should be done attentively.

Van Doremalen et al.

(2020) evaluated the stability of particles on several surfaces and concluded that viability on plastic and stainless steel surfaces gave an approximate half-life of 6.8 hours and 5.6 hours respectively. Dimensional stability is consequently affected and preservation methods include 2% Gluteraldehyde or 0.5% Sodium Hypochlorite.

1.5 Digital workflow

Digital workflow has been in continuous progress prior to the pandemic. But, throughout this unsettling period, they have proved to be most efficient and profitable and have vastly progressed since (Barenghi et al., 2021). Digital platforms have set a new standard by maintaining compatibility with patients during the pandemic. With a fully digital approach, the intraoral scanner can receive data and design the prosthesis accordingly with its corresponding software. In combination with CAD/CAM technology, the program will manufacture the definitive prosthetic restoration in a secure environment with reduced possible infection risk. Human intervention is regulated as there are no physical impressions as a digital file storage reduces cross contamination. Digital workflow implements comfort, support and safety during the pandemic in prosthodontic dentistry.

1.6 Removable Prosthodontics

Guan et al. (2020) concluded that age has been documented as a primary risk factor for increasing COVID-19 mortality rate, compounded with the presence of co-morbidities. Relatively with age, removable prosthodontics incorporates fabrication of complete and partial dentures. Removable partial dentures can either be made of acrylic resin, cobalt chrome or both and emergencies are commonly associated with denture fracture of either the acrylic, the metallic substructure or the clasps (Aldhuwayhi et al., 2021). Patients would complain of either pain or soreness in the soft tissue which restrains daily function and requires the prosthodontist and laboratory team urgently. Typically, the patients' master casts should be available and if not, treatment should be postponed and the prosthesis should not be used till the pandemic protocols facilitate treatment. Removable complete dentures are often made of acrylic resin and fractures are the most frequent complications associated with it due to poor design, poor fit, fault in fabrication or lack of balanced occlusion (Bilhan et al., 2012).

Management relies on the extensity of the fracture otherwise the patient is advised to stop using the prosthesis till the pandemic settles. Geriatric patients face special risks for COVID-19 and complete dentures are ordinarily offered to them. Assessment of risk and benefit along with a careful medical history is crucial when treating such patients. Priority is given to pending procedures to steer clear of unnecessary intricate circumstances. Chair side protocol should be minimized to a minimal. Mandatory visits and urgent repair of prosthesis should be disinfected and adjusted on strict appointment scheduling. Management of ulceration can be done through teleconsultation by prescribing local analgesics or discontinuation of the prosthesis temporarily or purchase sandpaper to gently smoothen sharp edges of the denture. Dentists are recommended to use low speed micro motor handpiece for any adjustment and one step border molding to cut clinical exposure. It is advisable to avoid contact and collect the denture from the affected patients and directly send them to the laboratory for repair with the purpose that it is carefully disinfected with Sodium hypochlorite. Technicians should follow biosafety recommendations to avoid cross contamination when handling the prosthesis. Any laboratory protocols should be adjusted in advance to secure less follow up visits by the patient.

1.7 Implant treatment

Surgical aerosol generating procedures highly contribute in the dynamic of indefinite risk posed by the respiratory pandemic. As per Shamsazadeh et al. (2020), slow speed drills and high volume suction is a must and use of ultrasonic devices and piezoelectric surgery should be minimized; whereas use of osteotomes should be encouraged to reduce aerosol formation. Most chronic emergencies associated with implant restorations include loosening, cement induced implantitis or missing access hole restoration (Pjetursson et al., 2012). This can cause food accumulation and esthetic complications. Patients might demand an immediate appointment as it instigates pain, functional difficulties and soft tissue impingement leading to discomfort and urgent attention. Loosened screws can be retightened and if possible fractured screws should be deferred as retrievability is extremely challenging during a pandemic outbreak. Full mouth rehabilitation should be postponed till advised otherwise. Laboratory protocols must be done carefully to avoid repetition and implant components must be disinfected meticulously before reusing them.

1.8 Role of teledentistry

Yoshinaga (2001) defined teledentistry as a combination of telecommunications and dentistry, involving the exchange of clinical information and images over remote distances for dental consultation and treatment planning. Rapid implementation of teledentistry during the COVID-19 lockdown reduced unwarranted clinical appointments which emphasized urgent and non-urgent case selection for specialists. One of the many advantages was to prevent sense of isolation, stress and psychological reassurance for geriatric patients. Most teleconsultations depended on high resolution photographs, past patient history and virtual examination. Most emergencies were managed by patients who were guided by the dentist via telecommunication and handled by a technician who would visit their residence to facilitate a temporary fix if the specialist was unavailable in their area due to lockdown. However, the role of teledentistry was confined in the prosthodontics field.

The principles in which teledentistry practice abided by followed standard in-person dental care principles. Both professional obligations and legal requirements like confidentiality were fundamental to ensure security and comfort bilaterally. Most concerns derived from confidentiality as patients were concerned with compromised discretion. Informed consent is foundational and should include risks of data leak and incorrect diagnosis and treatment given the circumstance and limited technology available. Teledentistry provided a conservative platform to ensure sustainable provision for oral care, manage emergency encounters and taper the risk associated with COVID-19 transmission throughout lockdown.

2. LITERATURE REVIEW

It is fundamentally important to appreciate the intricate composition of aerosols and their modes of transmission to implement ideal management strategies and avoid practical implications during practice. Additionally, this literature review evaluates other studies that analyzed aerosol transmission, its impact on clinicians and the significance of protection and prevention. Most of the experiments conducted in the studies encircled periodontal and surgical procedures, where the spread of aerosol was measured through ultrasonic scalers or surgical motor handpieces for extraction. There was very limited data available on restorative crown procedures. Aerosolization is evident throughout prosthodontic procedures and though literature is conflicted, there is a broad gap in studying aerosol spread within these procedures.

2.1 Aerosol transmission

Aerosolized transmission is believed to be the main mode of infectious transmission, predominantly in healthcare sectors. Aerosol generating procedures take place in the dental clinic or through aerosol expulsion of droplets from the oral cavity by coughing or sneezing. Procedures such as spitting, extraction or tooth drilling place dentists at high risk of exposure. Dental clinics host fomites that can be inhaled or ingested making patients and dentists vulnerable to exposure. Even asymptomatic COVID-19 positive patients account for infection, suggesting that aerosols, droplets and direct contact support the dynamic for human-to-human transmission (Seo et al., 2021). The leading path of transmission of the COVID-19 pathogenic microorganism is multifactorial. It is through direct contact with blood, oral fluids or aerosols generated by high speed headpieces or ultrasonic instruments from an infected other. In addition to patients that need to gargle post extraction, abscess drainage and drilling. This in result is projected at short distance through coughing and face to face communication. As per Dhand and Li (2020), even airborne particles that remain suspended in the air can be inhaled and trigger the infection.

Almost all dental procedures entail risk and studying the intensity of aerosol transmission can help define the level of risk that each procedure generates. Accordingly, define the appropriate personal protective equipment. Most dental equipment is made up of metal and polymers where “COVID-19 particles” can cohere and linger. This could heighten the possibility of contamination. Eye exposure has also been reported as a route of transmission for the virus (Passarelli et al., 2020). Eye symptoms are not a common indicator but some conjunctival samples confirmed that 2019-nCoV is not confined to the respiratory system. Throughout all the investigations undergone to date, two modes of transmission predominantly exist - direct and indirect. The direct mode includes aerosol generation formed via surgical and dental procedures and/or in the form of respiratory droplet nuclei. SARS-CoV-2 is thought to commonly spread via respiratory droplets formed while talking, coughing, and sneezing of an infected person. The exposure and, hence, risk of transmission are increased if the infected person is present within 1m length of susceptible host. Karia et al. (2020) stated that indirect transmission may occur via surfaces (e.g. furniture and fixtures) present within the immediate environment of an infected patient and objects used on the infected person (e.g. thermometer). Therefore, airborne aerosol transmission is a potent mode of transmission. Contamination is dependent on saliva, blood, nasal and pharynx secretion, periodontal infection and dental plaque. Kleinstein et al. (2020) claimed that subgingival plaque and its pathogenic composition in patients with periodontitis are associated with cardiovascular and respiratory diseases and diabetes mellitus and therefore prone to higher risk of infection. Potential modes of spread and their admissible accuracy are yet to be assessed. Because cold and flu viruses can be transmitted by contact, contaminated objects and an airborne route, in a flu out- break it often is difficult to know the exact route by which the virus is transferred (Harrel and Molinari, 2004). The literature is yet to explore the effectiveness of distribution and its relation to clinical settings (Jarvis, 2020), the uncertainty about the definitions of aerosols and airborne droplets and their relative size and number in aerosol generated procedures (Vuorinen et al., 2020) and the lack of precision regarding definition for aerosol generating procedures (WHO guidelines, 2014).

2.2 Dental aerosol

The terms “aerosol” and “splatter” in the dental environment were used by Micik et al. (1969). Aerosols express themselves as particles smaller than 50 micrometers in diameter while splatters are described as particles larger than 50 micrometers. Aerosols are a mixture of liquid and solid particles, when the liquid evaporates, the solid remains and forms a droplet nuclei (0.5-10μm) composed of saliva, dried serum and microorganisms. Micik also acknowledged that they can infiltrate the pulmonary alveoli, reside in the atmosphere and travel further promoting higher levels of threat in a dental setting. Splatter is a mixture of solid, liquid and air particles (50μm). Because of their mass, the particles move in a ballistic way and inhabit objects with limited infiltration into the respiratory system. The composition of dental aerosols is merely impossible to investigate as they are dependent on the patient and the corresponding procedure (Nobrega et al., 2021). With the use of the high-speed rotary handpiece during tooth preparation, aerosol particles are generated and form an apparent cloud of particulate which includes matter emerging from the treatment and the dental unit waterline. This concern is picked up by the dentist, the assistant and the patient. The imperceptibility of this cloud should be recognized and constrained to reduce all potential risks associated with the transmission of the virus and reassure the patient.

Several studies have been performed to demonstrate which dental procedure generates the greatest airborne bacterial contamination such as those by Jain et al. (2020), Monarca et al. (2000), Polednik (2014) and Rautemaa et al. (2006). The ultrasonic scaler has been shown to produce the greatest amount of airborne contamination, followed by the air-driven high-speed handpiece, the air polisher and various other instruments such as the air- water syringe and prophylaxis angles (Harrel et al., 2004). Most prosthodontic procedures are subjected to extensive use of a high-speed handpiece, making it necessary to study and understand the intensity of aerosol transmission. Most dental procedures claim high-speed handpieces where excessive heat is produced due to the friction between the tooth and the bur, wherefore a water coolant is necessary to prevent further damage to the hard-dental tissue. Consequently, aerosols are generated and inflict further risk to both patients and dentists. The dental unit waterlines that supply handpieces are an alternative source of infectious transmission in a dental setting. They possess microorganisms provoked by the narrow line design, water stagnation and warming of dental chair (Spagnolo et al., 2020). These microorganisms may deposit into the oral cavity and induce more spread. Handpieces, ultrasonic scalers and air polishers produce aerosols by rotary mechanism and ultrasonic vibrations. They are evident to the naked eye and noticed by the patient and dental staff. They have potential to travel as far as ventilation systems and access other operating sites in the dental clinic. Hinds (1982) concluded that a true aerosol or droplet of nuclei may be present in the air of the operatory for upto 30 mins after a procedure. This indicates that even after the procedure is finished, the dentist should withhold taking of their facemask to avoid inhaling the airborne contamination lingering.

Micik and Miller (1969) have determined that bio-aerosols can contain millions of bacteria per cubic foot of air. However, when we look at a study by Harrel et al. (1998) on splatter and aerosol generated from an ultrasonic scaler without any coolant water used in vitro, there was still a substantial number of aerosol and splatter formed from small amounts of liquid placed at the operating site to simulate blood and saliva. In most dental aerosol generating procedure such as restorative procedures, it is common to detect blood contamination. It is recommended to eliminate airborne contamination before it leaks into the critical surrounding and the use of high volume suction along with the saliva ejector commonly used as it is not sufficient on its own. During restorative tooth preparation, the dental assistant is required to guide and target the high-volume suction to reduce the aerosol generated to a feasible extent. We therefore must look at ways to mitigate this risk during the current SARS-CoV-2 crisis (Nulty et al., 2020).

2.3 Impact on dentists and dental practice

As Tonkaboni et al. (2021) stated, the risk of bidirectional spread of infection between patient and dental care providers makes it critical to take additional precautionary measures to mitigate the spread of COVID-19. Pathogenic viruses such as SARS impose a high risk of exposure as transmission is assisted throughout dental procedures. Due to the virus's challenging interpretation of origin and its consequence, dentists are highly impacted ceasing all forms of dental treatment apart from selective emergency treatments within such a pandemic. Incubation period as frequently stated varies within 7-24 days, where patients exhibit no symptoms. Therefore, both patients and dental professionals are at a bilateral risk of being exposed to viral pathogens that can be transmitted through the oral cavity and respiratory tract during dental visits (Barabari and Moharamzadeh, 2020).

Access to oral health care has been severely restricted and patients are either reluctant or unable to access dental care plus there will be an enduring time for recovery. There was a high volume of attention in regards to what was considered as urgent treatment and selective treatment leading to an exponential interest to know more about the disease. However, suspending dental routine care led to denied and/or delayed oral care which sooner or later influenced quality of life. There is an apparent lack of data for prosthodontic procedures that generate airborne particulates contaminated with viruses, blood and bacteria. This research aims to study a simple prosthodontic procedure conducted under assorted precautionary methods to develop an established guideline to follow and appreciate the level of protection necessary.

All emergency dental treatments were managed on remote facility sites and through teleconsultation. Teleconsultation was highly regarded as face to face communication was cut and so was transmission consequently. With COVID-19, fear and distress is evident among the community and patients may confide in elective treatment strictly. The obligation to limit working hours for dentists has integrated psychological stress as they were expected to execute versatile standard health and safety protocols during the pandemic. The consequence of COVID-19 stress has left marks in patients mouths as they have been clenching and grinding which led to cracked teeth, fractured fillings and pain (Dadnam et al., 2021). Even poor eating habits have manifested in their mouths and negatively impacted their teeth. The pandemic has given rise to personal hygienic awareness and an increased attention to oral care. The economic sector in dental practice is broadly affected as cost of delivering treatment arose. Social implications, financial sustainability and delivery of care has shaped dentists throughout COVID-19. The pandemic quantified the financial cost required for the preventive measures used and their purchase rate. Teleconsultation, auxiliary resources, modified clinical setting and reduced patient flow (Haleem et al., 2021) contribute to increase in demand.

Immediate effect of COVID-19 on treatments was noticed very soon after the announcement to prohibit complex treatment. The prolonged period of vigilance led to patients being irregular participants which developed into infection related complications. It is only natural to expect that an increase in teeth with poor prognosis led to extraction and will potentially lead to an increased demand for prosthetic replacement, such as implant or fixed/removable prosthetic work. Due to limited prosthetic treatment access, edentulism should anticipate a leap in ratio in correspondence to lack of acceptable mastication and quality of life. This will also support replacing conventional impressions with digital intraoral scanners, computer aided design (CAD/CAM) work and the use of 3D-printing technology.

2.4 Protection and prevention

The continuous flux of COVID-19 guidelines have made it difficult for dentists to navigate clinical workflow and avoid contagion (Benzian et al., 2021). Experimental studies have facilitated an overview in which practitioners can streamline methodized clinical decisions with appropriate infection control protocols. These studies support a holistic system driven approach to combat the pandemic effectively. Harrel et al. (2004) wrote that no single approach or device can minimize the risk of infection to dental personnel and other patients completely. A single step will reduce the risk of infection by a certain amount, another step added to the first step will reduce the remaining risk, until the risk is minimal. Personal protective equipment has met an exponential rise in the market which casted increased anxiety within clinicians. In addition to all the protective layering required, doffing and donning PPE has become increasingly time consuming and challenging. During all procedures, it is substantial that surgical masks, face-shields and eye protection are used. However, during aerosol generating procedures face-shields in addition to N95 masks should be worn. As per Centers for Disease Control and Prevention, long-sleeved, high neck non-surgical gowns should be worn by the dentist, staff involved in patient care and those handling instruments such as laboratory technicians and cleaners. It is advised to change gowns amidst patients but due to shortage of protection wear, it is also reasoned to change when contaminated. Gloves and foot covers are instrumental by those undertaking or assisting procedures. Following every procedure, it is recommended to leave the door closed with an hour span of sterilization. It is advantageous to divide the practice staff so that the full operational balance is not compromised.

Secondary measures should be available when carrying out aerosol generating procedures such as extra oral suction, rubber dams and external ventilation. Disposable equipment is largely appreciated when handling high risks of cross contamination. All other instruments that have been exposed to the oral cavity should be disinfected and sterilized per manufacturer's instructions before use on another patient. The use of strict system of zoning in the clinic will reduce the number of areas contaminated and therefore facilitate maintenance of asepsis (Clare, 1991).

2.5 Dentistry after the vaccine

To date, worldwide pharmaceutical companies have developed multiple vaccinations with different individual modes of action in contribution to the immunity of the population. Throughout each wave in the pandemic, individuals within certain age groups were gradually eligible to take the vaccine to control the rate of infectivity. It was mandatory for healthcare workers or front-liners such as dentists to receive the vaccination to ensure patient safety when operating. In principle, health care professionals held responsibility in delivering awareness and encouraging patients to take the COVID-19 vaccine. It was and still is challenging as it raised concerns against its safety and effectiveness which impacted its acceptance rate. Though all vaccines demonstrated high success rates, it ensured that dental practice is almost completely safe if practiced within precautionary limitation, for example Burbank Dental Implants Reports stated that it is safe to get dental implants after getting vaccinated.

Knowledge circulating the vaccine is still a working progress and it is crucial to understand that despite the vaccination status, it does not eradicate the probability of acquiring the virus.

Other studies;

3. AIM

The purpose of this study is to explore and evaluate aerosol generation and spread by developing an established laboratory dependent approach strictly simulating prosthodontic aerosol generating procedures. The primary objective is to measure the intensity of aerosols within specified distance marks transmitted in the alleged environment accordingly and the secondary objective is the prevention required to minimize the consequence of transmission. The null hypothesis was that there is no significant difference in the amount of aerosol production with or without preventive measures.

3.1 Specific objectives:

1. To visualize and detect the dispersion of aerosols using robust resources and equipment such as detectable acid, universal indicating paper, camera lens and an image analysis software.
2. To compare the distance and intensity of the aerosol transmission amongst each location.
3. To determine the efficacy of using auxiliary measures to minimize contamination such as extra oral suction.
4. To highlight the magnitude of protection required in each procedure using the necessary PPE

4. MATERIAL AND METHODS

The experimental study was conducted in Mohammed Bin Rashid University, United Arab Emirates in the 8x5m dental simulation laboratory. The mock crown tooth preparation procedures were performed on the upper right central incisor (tooth 11, FDI World Dental Federation notation) and upper right first molar (tooth 16, FDI World Dental Federation notation) on a phantom head mannequin including Nissin (A5AN-200, Nissin Dental Products Inc., Japan) model teeth in both jaws. The sum of tooth #11 and tooth #16 used were (n=10) each. The phantom head and body was placed at a supine position, replicating the standardized clinical scenario. Citric acid crystalline powder (Intra Laboratories Ltd, Plymouth, UK) was diluted with distilled water to give a 10g/100ml final solution. The solution was injected into the water line of the dental unit. Latex was fitted in the manikin's mouth to simulate the volume of the human oral cavity. The role of the assistant was undertaken by a "simulated assistant" posing accurately as a stand and a flip chart was assigned 30cm behind the phantoms head. Litmus blue paper (10x67mm, Johnson test papers, United Kingdom) were allocated on the following four zones: operator's faceshield (at 9o'clock), operator's chest (at 9o'clock), simulated assistant's chest (at 2o'clock) and 30cm distance behind the phantoms head (at 12o'clock) as shown in figure 1. The operator remained in the same position at 9-10 o'clock.

The universal indicator paper (UIP)/litmus paper interprets chromatic color change due to its PH sensitivity and displayed an acidic (red) color, therefore visualizing the scatter. The high-speed air turbine handpiece (400,000 rpm, B.A. International Ltd, United Kingdom) fitted with a diamond tapered chamfer round end bur (SKU C856/018, Candent, Canada) was used for the referenced procedures. The water flow rate was adjusted to manufacturer’s instructions and set to 12-14 mL/min. Circumferential tooth drilling included buccal, mesial, distal and palatal wall preparation. Considering the assistant was simulated, only low volume suction was used. To optimize the methodology, a prosthodontic post graduate resident performed the procedure of anterior and posterior full crown preparation. The extra oral suction (Greeloy, China, 4000L/min suction rate) was used as an auxiliary measure for comparison. The collecting cone was placed at an approximation of 5 ± 1 inches perpendicular from the oral cavity which enabled access for tooth preparation without any interference. As per nature of the scenario and the nature of acid the operator was covered in the appropriate personal protective wear including a head mask, face mask, protective goggles, face-shield, body gown and dental gloves.

The litmus paper was removed at the end of each experiment and packaged for analysis. Every procedure was performed for 15 minutes on a stopwatch. The experiment was repeated five times to obtain an average with the least account for standard deviation. Regarding the control groups, one piece of uncontaminated blue litmus paper and one blue litmus paper entirely drenched in 10% citric acid was processed through the software and analyzed. The litmus paper collected was photographed (Nikon D3500 DSLR Camera) and uploaded onto the computer. The photographs were taken under identical conditions and labelled per relative location. The data was analyzed through Fiji-ImageJ software and assessed through color intensity. The results were charted in the following categories; location of litmus paper, anterior or posterior tooth number, color pixel values, and with or without extra oral suction.

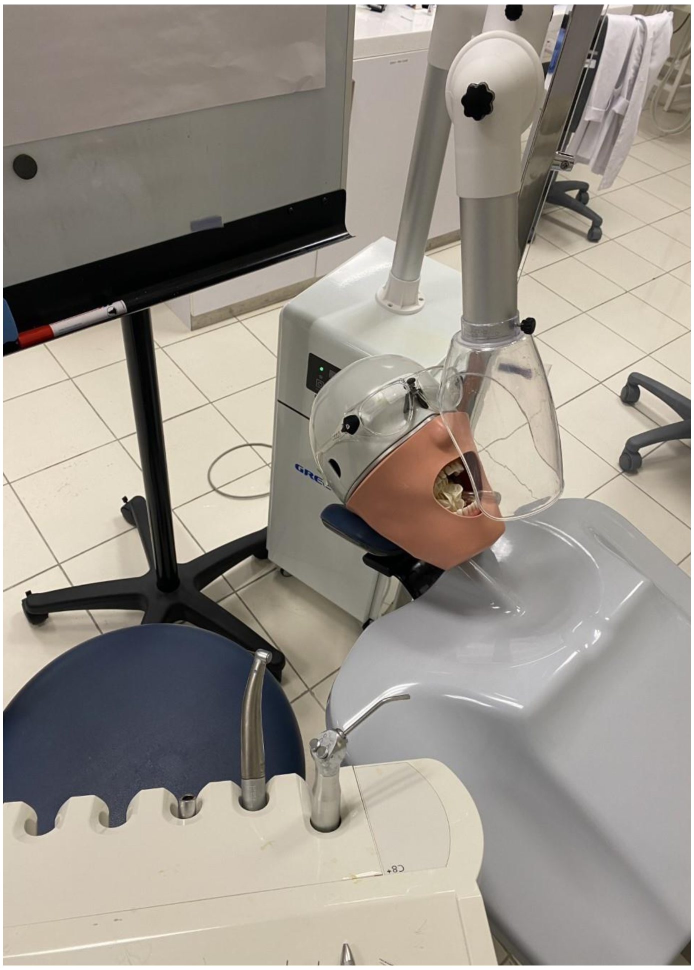
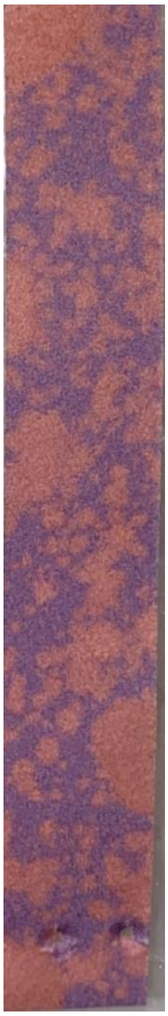


Figure 1 - *Simulated dental setting with UIP at 30cm distance behind the mannikin's head and simulated assistant's chest with the use of EOS*.

4.1 Statistical analysis

Images at each designated location were uploaded using Fiji-ImageJ software to analyze the color intensity through a color histogram displaying red, green and blue mean values. The collected data was entered on the computer using IBM-SPSS for Windows version 28.0 (SPSS Inc., Chicago, IL). The Shapiro-Wilk test was used to investigate the normality of the continuous variables (i.e. red, green and blue). A multivariate analysis of variance (MANOVA) was used to study the relationships among the five attributes present in this study which include red, green and blue values, location of UIP, tooth number and presence of EOS. The analysis was used to classify the eight collected categories into homogenous groups and mark the interferences in the underlying populations from the sample. The post hoc test was implemented to establish where the significant differences were. The Mann-Whitney test was used to compare whether there was a difference in the dependent variable for the two independent groups. The non-parametric Kruskal-Wallis test was used to compare the means between more than two groups. A P-value of less than 0.05 was considered significant in all statistical analysis.

(2)



(3)

Figure 2 *- UIP at least contaminated site - operator's face-shield for tooth #11*

Figure 3 *- Contaminated UIP at operator's chest for tooth #11*

Figure 4 *- UIP at most contaminated site - 30cm behind manikin's head for tooth #11*

5. RESULTS

The data (table 1) describes the mean and the standard deviation calculated and tabulated to generate a descriptive statistical analysis to summarize the quantitative observations made in this experiment. Both upper right central incisor (tooth #11) and upper right first molar (tooth #16) exhibited an average lower mean value when extra oral suction was used compared to no extra oral suction used. This revealed a favorable supposition to the efficacy of using auxiliary measures to minimize contamination.

Table 1 - Intensity of aerosols by different color, tooth and location

	Tooth 11		**Tooth 16**	
Extra oral suction used	No EOS	With EOS	No EOS	With EOS
Red	Mean (SD)		Mean (SD)	
Operator's face-shield (9)	91.38 (0.98)	73.35 (0.78)	82.17 (1.83)	65.13 (1.25)
Operator's chest (9)	141.04 (3.21)	104.07 (4.29)	116.4 (4.4)	88.76 (3.9)
Simulated assistant's chest (2)	122.28 (3.84)	96.7 (1.87)	116.92 (1.72)	101.86 (386)
30cm distance (12)	157.64 (0.68)	132.68 (1.68)	122.49 (2.89)	101.68 (2.01)
Green				
Operator's face-shield (9)	91.53 (0.58)	71.75 (0.71)	90.91 (1.06)	72.15 (1.03)
Operator's chest (9)	92.78 (2.30)	72.24 (1.54)	89.26 (1.95)	69.04 (1.9)
Simulated assistant's chest (2)	89.11 (1.24)	69.01 (1.23)	88.77 (1.72)	74.91 (1.43)
30cm distance (12)	103.84 (0.27)	86.96 (1.23)	93.21 (2.8)	76.33 (1.7)
Blue				
Operator's face-shield (9)	145.61 (0.55)	115.36 (0.86)	156 (1.61)	124.21 (0.98)
Operator's chest (9)	109.84 (5.36)	86.3 (1.7)	120.21 (0.72)	93.91 (2.59)
Simulated assistant's chest (2)	119.10 (3.31)	91.33 (2.84)	120.11 (3.21)	97.39 (1.9)
30cm distance (12)	105.02 (0.19)	87.42 (0.95)	120.1 (16.11)	97.39 (1.9)

When the citric acid (10%) aerosol contacted the blue litmus paper, the chromatic color change was displayed as red. The highest mean(SD) value in red was 157.64(±0.68) at 30cm behind the manikin's head and the highest value in blue was 156(±1.61) at the operators face-shield. In contrast, the lowest mean(SD) value recorded in red was 65.13(±1.25) at the operator's face-shield and the lower value recorded in blue was 86.3(±1.7) at the operators' chest.

In depth when comparing red values between tooth numbers; anterior (#11) and posterior (#16), the highest mean(SD) value in red on tooth #11 was 157.64(±0.68) and on tooth #16 was 122.49(±2.89). Both results were obtained at the same location which was 30cm behind the manikin's head. As opposed to the lowest recorded mean(SD) values in red on tooth #11 was 73.35(±0.78) and on tooth #16 was 65.13(±1.25). Once again, both results were collected at the same location which was at the operator's face-shield.

Additionally, when comparing blue values between tooth numbers; anterior (#11) and posterior (#16), the highest value in blue on tooth #11 was 145.61(±0.55) and on tooth #16 was 156(±1.61). The pair shared the same location which was at the operator's face-shield. In comparison to the lowest values in blue on tooth #11 was 86.3(±1.7) and on tooth #16 was 93.91(±2.59) accordingly. Both together sharing the same location which was the operator's chest. This linearity indicates a commendatory constant relationship between the results.

For tooth #11 and #16, the percentage decrease between no extra oral suction and with extra oral suction was calculated for mean(SD) values red and blue. The total percentage decrease was calculated and divided by 8. An average of 20.6% and 19.2% percentage decrease was seen respectively, with the highest percentage decrease noted in tooth #11 was 26.21% and in tooth #16 was 23.74% at the operator's chest.

Table 2 - Test of normality using Shapiro-Wilk

		Statistic	df	P-value
Red	Tooth 11	0.939	40	0.031
	Tooth 16	0.926	40	0.012
Green	Tooth 11	0.886	40	<.001
	Tooth 16	0.883	40	<.001
Blue	Tooth 11	0.884	40	<.001
	Tooth 16	0.148	40	<.001

The null hypothesis was that there was no significant difference found in the amount of aerosol generation with or without preventive measures. Due to the small sample size (df= 40), an appropriate non-parametric statistical method had to be used to establish the distribution of the variables. The Shapiro-Wilks test (table 2) conducted confirmed the variables are not normally distributed. The distributions were significantly non-normal for each variable (W=0.939, p=0.031), (W=0.926, p=0.012), (W=0.886, p <0.001), (W=0.883, p<0.001), (W=0.884, p<0.001) and (W=0.148, p<0.001) respectively. The null hypothesis was rejected as the P-value shown was less than <0.05.

Table 3 - Multivariate analysis to test between subject effects

Source	Dependent Variable	F-value	P-value
Corrected Model	Red	407.61	<.001
	Green	253.00	<.001
	Blue	1.00	0.467
Intercept	Red	120915.93	<.001
	Green	239742.27	<.001
	Blue	1.18	0.281
Location	Red	1180.12	<.001
	Green	182.27	<.001
	Blue	1.00	0.4
EOS	Red	1424.53	<.001
	Green	2921.61	<.001
	Blue	0.98	0.326
Tooth	Red	629.71	<.001
	Green	69.28	<.001
	Blue	1.01	0.319
Location * EOS	Red	27.08	<.001
	Green	6.49	<.001

	Blue	1.00	0.398
Location * Tooth	Red	134.25	<.001
	Green	72.07	<.001
	Blue	1.00	0.399
EOS * Tooth	Red	25.71	<.001
	Green	7.76	0.007
	Blue	1.00	0.321
Location * EOS * Tooth	Red	3.28	0.026
	Green	4.64	0.005
	Blue	1.00	0.398

In this study, MANOVA was used to distinguish whether the following independent variables singularly or in conjunction with one another influence the dependent variables. As shown in the table (table 3), the Test of Between-Subjects Effects was used to assess the significance of differences between the mean values and illustrate the corrected model (sum of squares excluding intercept), intercept estimate (the constant), the F values and significance levels (p-value) in each dependent variable.

The f-value is calculated as the variation between the sample means/ variation between samples. The f-value is inversely proportional to the p-value. Based on that, the f-value in all the independent variables alone or in combination with one another showed an average value of 0.99 for blue with a corresponding average p-value of 0.365, signifying no effect observed on blue regardless of the independent variable. In opposed to the rest of the results where the f-value showed an average value of 489.24 for red with a corresponding average p-value of 0.004. The highest variation for red was observed when using EOS, 1424.53 p <0.001. This supports rejecting the null hypothesis. When all 3 independent variables and their corresponding f-values were assessed for significance, no integration was found concluding no further analyzation required. Alternatively, Pillai's trace, Wilks' lambda, Hotelling's trace and

Roy’s largest root can be used instead of relying on the f-value as a marker of significance as shown in table 4 below.

Table 4 - Multivariate analysis

	Value	F-value	Hypothesis df	Error df	P-value
Pillai's trace	1.871	35.368	9	192	<.001
Wilks' lambda	0.002	182.904	9	151.042	<.001
Hotelling's trace	62.235	419.508	9	182	<.001
Roy's largest root	56.181	1198.519a	3	64	<.001

Pillai's trace is the most robust test statistic used for MANOVA and its value ranges from 0-1. The closer it is to 1, the more potent and significant the effect on the dependent variables. Evidently, as shown in table 4, the value is 1.871 $p<0.001$. Therefore, we can reject the null hypothesis of the MANOVA conducted.

Table 5 - Multivariate comparison - Post hoc test

			P-value
Red	Operator's face-shield (9 o'clock)	Operator's chest (9 o'clock)	<.001
		Simulated assistant's chest (2 o'clock)	<.001
		30cm distance (12 o'clock)	<.001
	Operator's chest (9 o'clock)	Operator's face-shield (9 o'clock)	<.001
		Simulated assistant's chest (2 o'clock)	<.001
		30cm distance (12 o'clock)	<.001
	Simulated assistant's chest (2 o'clock)	Operator's face-shield (9 o'clock)	<.001
		Operator's chest (9 o'clock)	<.001
		30cm distance (12 o'clock)	<.001
	30cm distance (12 o'clock)	Operator's face-shield (9 o'clock)	<.001
		Operator's chest (9 o'clock)	<.001
		Simulated assistant's chest (2 o'clock)	<.001
Green	Operator's face-shield (9 o'clock)	Operator's chest (9 o'clock)	0.121
		Simulated assistant's chest (2 o'clock)	0.021
		30cm distance (12 o'clock)	<.001
	Operator's chest (9 o'clock)	Operator's face-shield (9 o'clock)	0.121

		Simulated assistant’s chest (2 o’clock)	0.432
		30cm distance (12 o’clock)	<.001
	Simulated assistant’s chest (2 o’clock)	Operator’s face-shield (9 o’clock)	0.021
		Operator’s chest (9 o’clock)	0.432
		30cm distance (12 o’clock)	<.001
	30cm distance (12 o’clock)	Operator’s face-shield (9 o’clock)	<.001
		Operator’s chest (9 o’clock)	<.001
		Simulated assistant’s chest (2 o’clock)	<.001
Blue	Operator’s face-shield (9 o’clock)	Operator’s chest (9 o’clock)	0.993
		Simulated assistant’s chest (2 o’clock)	0.164
		30cm distance (12 o’clock)	0.993
	Operator’s chest (9 o’clock)	Operator’s face-shield (9 o’clock)	0.993
		Simulated assistant’s chest (2 o’clock)	0.162
		30cm distance (12 o’clock)	1
	Simulated assistant’s chest (2 o’clock)	Operator’s face-shield (9 o’clock)	0.164
		Operator’s chest (9 o’clock)	0.162
		30cm distance (12 o’clock)	0.162
	30cm distance (12 o’clock)	Operator’s face-shield (9 o’clock)	0.993
		Operator’s chest (9 o’clock)	1
		Simulated assistant’s chest (2 o’clock)	0.162

The multivariate comparison concluded significant difference between the independent variables. Therefore, a more meticulous approach was required. The post hoc test was implemented to establish where the significant differences were.

With regards to the red value, every independent variable was tested against the other independent variable to locate the significant difference. For instance, in case of the *operator’s face-shield* x operator’s chest or *operator’s face-shield* x simulated assistant’s chest or *operator’s face-shield* x 30cm distance, all values showed no significant difference. In fact, when all independent variables were placed in versus with the other independent variables, the red p-value was always <0.001. This indicates that location expressed a significant factor in aerosol contamination.

However, regarding the blue value, every independent variable was also tested against the other independent variable and in this case, the contrary was true. As notably shown in table 5, the *operator's face-shield* x operator's chest or *operator's face-shield* x simulated assistant's chest or *operator's face-shield* x 30cm distance showed no significant difference. When all independent variables were placed in versus with the other independent variables, the blue p-value was always <0.001. This indicated that the blue values were certainly representing the control value.

Table 6 - Comparison between intensity by location for tooth #11

	No extra oral suction used		**Extra oral suction used**	
Location	Mean (SD)	P-value	Mean (SD)	P-value
Red				
Operator's face-shield (9 o'clock)	91.38 (0.98)[1]	<0.001	73.35 (0.78)[1]	<0.001
Operator's chest (9 o'clock)	141.04 (3.21)[2]		104.07 (4.29)[2]	
Simulated assistant's chest (2 o'clock)	122.28 (3.84)[3]		96.7 (1.87)[3]	
30cm distance (12 o'clock)	157.64 (0.68)[4]		132.68 (1.68)[4]	
Green				
Operator's face-shield (9 o'clock)	91.53 (0.58)[1]	0<0.001	71.75 (0.71)[1]	<0.001
Operator's chest (9 o'clock)	92.78 (2.3)[1]		72.24 (1.54)[1]	
Simulated assistant's chest (2 o'clock)	89.11 (1.24)[2]		69.01 (1.23)[2]	
30cm distance (12 o'clock)	103.84 (0.27)[3]		86.96 (0.88)[3]	
Blue				
Operator's face-shield (9 o'clock)	145.61 (0.55)[1]	<0.001	115.36 (0.86)[1]	0.001
Operator's chest (9 o'clock)	109.84 (5.63)[2]		86.30 (1.7)[2]	
Simulated assistant's chest (2 o'clock)	119.10 (3.32)[3]		91.33 (2.84)[3]	
30cm distance (12 o'clock)	105.02 (0.19)[4]		87.42 (0.95)[2]	

1,2,3,4 indicate the pairwise comparisons, the same number means not significant

A pairwise comparison test was then conducted to analyze the relationships between pairs of means for each independent variable. Table 6 distinctly analyzes pairwise comparisons for tooth #11 with and without extra oral suction at each designated location. Each mean value was given an index (1-4) and if the numbers are identical means no significance recognized.

For each red mean(SD) value at each location, none of the values shared a pair of identical indices regardless if EOS was present or not. This indicates the significance and that at every location, no identical concentration of aerosols was observed. For each blue mean(SD) value at each location, none of the values shared a pair of identical indices except for the operator's chest and at 30cm distance (2) when the extra oral suction unit was used. This indicates no significance and that a similar pattern of UIP left uncontaminated was seen in both locations.

Table 7 - Comparison between intensity by location for tooth #16

	No extra oral suction used		**Extra oral suction used**	
Location	Mean (SD)	P-value	Mean (SD)	P-value
Red				
Operator's face-shield (9 o'clock)	82.17 (1.82)^1	0.002	65.13 (1.25)^1	<0.001
Operator's chest (9 o'clock)	116.4 (4.4)^2		88.76 (3.9) ^{2}	
Simulated assistant's chest (2 o'clock)	116.4 (1.7)^2		101.86 (386)^3	
30cm distance (12 o'clock)	122.49 (2.89)^1		101.68 (2.01)^3	
Green				
Operator's face-shield (9 o'clock)	90.91 (1.06)^1	0.027	72.15 (1.03)^1	0<0.001
Operator's chest (9 o'clock)	89.26 (26)^1		69.04 (1.9) ^{2}	
Simulated assistant's chest (2 o'clock)	88.77 (1.72)^1		74.91 (1.43)^1	
30cm distance (12 o'clock)	93.21 (2.8)^2		76.33 (1.7)^3	
Blue				
Operator's face-shield (9 o'clock)	156 (1.62)^1	0.011	124.21 (0.98)^1	<0.001
Operator's chest (9 o'clock)	120.21 (0.72)^2		93.91 (2.59)^2	
Simulated assistant's chest (2 o'clock)	120.11 (3.21)^2		97.39 (1.9)^3	
30cm distance (12 o'clock)	120.1 (3.72)^2		97.39 (1.9)^3	

1,2,3,4 indicate the pairwise comparisons, the same number means not significant

The same pairwise comparison was conducted for tooth #16 (table 7) with and without EOS to analyze the resemblance in aerosol splatter. Results for the posterior tooth preparation were not as linear as there was identical pairing in red mean(SD) values between the operator's face-shield and 30cm distance and between the operator's chest and the simulated assistant's chest when no EOS was used. Likewise, for simulated assistant's chest and 30cm distance when EOS was present.

Regarding the blue mean(SD) values, same number pairing was seen in most locations including the operator's chest, simulated assistant's chest and 30cm distance without EOS. As for operating with EOS, both simulated assistant's chest and 30cm distance exhibited same number pairing. This indicated that when posterior tooth preparation for #16 was done, there was no significance between aerosol concentration and most allocations.

6. DISCUSSION

Dental practices were confronted with significant challenges throughout the global coronavirus disease (COVID-19) due to the unique characteristics of dental treatments and the high level of aerosol generation associated with an abundance of risk. The outbreak transitioned stable clinical awareness to great uncertainty, still projecting global manifestations to date. It also manifested great demand for consultation and emergency treatment regardless of its aggressive nature. With robust evidence constantly developing, the aim of this study was to try and unravel various facets of the pandemic in prosthodontic dentistry without rendering quality and standard of care. Since the outbreak, multiple methods have been implemented to evaluate the spread of aerosols in simulated dental procedures and by mapping the distribution of these aerosols we can establish precautionary protocols accordingly so that none of the dental emergencies are left unattended to through any pandemic. In the context of COVID-19, it is merely impossible to suppress the risk posed by dental aerosols but by understanding the phenomena it is possible to restore dental services with appropriate personal protective equipment in any pandemic. This study focused on the intensity of aerosol contamination relating to a particularly common dental procedure, tooth preparation for a prosthetic crown restoration.

Aerosols are a mixture of liquid and solid particles, when the liquid evaporates, the solid remains and forms a droplet nuclei (0.5-10μm) composed of saliva, dried serum and microorganisms. This is equivalent to the copious amounts of particulate matter (PM_{10} or 10μm) produced during restorative crown preparation (Sotiriou et al., 2008). In this study, tooth #11 and #16 were selected for contrast and their proximity to the operator. The result of the current study showed statistical significant difference in aerosol splatter intensity when using

EOS compared to when no EOS was used. The average percentage decrease of aerosol contamination for tooth #11 and #16 was 20.6% and 19.2% respectively. Findings in another study by Shahdad et al. (2020), with similar methodization concluded that EOS resulted in 20% reduction in frequency of contamination in the following operatory sites; the chest, face-shield, forearms, feet of both assistant and clinician. Given their study focused on an air turbine procedure, a surgical procedures and ultrasonic scaling on the anterior left central incisor (#21) there was no detail to the restorative procedure conducted.

All allocated sites perceived varying levels of contamination but the most considerable contamination (highest mean(SD) red value) recorded was 30cm behind the manikin's head while operating on tooth #11 without EOS. Distances up to 1.2m have reported positive readings for aerosol contamination. In one study by Ahmed and Jouhar (2021), it was deduced that aerosol and splatter can spread up to 36 inches; therefore, it is desirable to make an arbitrary "red zone" around the dental unit. This zone should have confined access to avoid contagion. Ishihama et al. (2009) found that presumptive blood contamination during oral surgery procedures was highest at a location of 20cm (76%), decreasing with distance (60% at 60cm) and (57% at 100cm). Bearing in mind, blood and water splatter at distinctive rates, at a 50cm behind the patient, Yamada et al. (2011) concluded the mean value for blood exposure was (0.87/min) in comparison to crown preparation (0.15/min). Only in one other study by Allison et al. (2021), aerosol generation was measured for anterior crown preparation on tooth #11 and investigators concluded that at distances beyond 0.5 m, risk of contamination is likely to be lower. Though this experiment only measured contamination coverage upto 30cm behind the manikin's head, combining these results with the literature we can establish that a perimeter of less than 50cm exposes both the clinician and the assistant to risk. This is worth considering if the operator is working at a 12 o’clock position for anterior restorative procedures.

In this study, parameters such as the operator's chest at 3 o'clock and the simulated assistant's chest at 2 o'clock were considered. Based on our results, the simulated assistant's chest for both tooth preparation on #11 and #16 displayed relatively high red mean(SD) values without EOS. This was also evident in another study by Veena et al. (2015) where investigators established that the 4 o'clock and 8 o'clock positions were the most and least contaminated areas, respectively, in a 30cm radius. Therefore, it is implied that one of the riskiest contamination sites lie at the left side of the patient towards the assistant. This signifies the importance of PPE for the whole dental team professionals.

Meanwhile, the least contamination (lowest mean(SD) blue value) was observed in the operator's zone on the operators face-shield, in both anterior and posterior tooth preparation without EOS. This might sound unpredictable considering the vicinity between the operator and the patient. Allison et al. (2021) established that the operator and the assistant's masks showed low but measurable contamination, usually at the lateral edges. In this study, operator remained in the same 9 o'clock position throughout all procedures, this is untypical. Other factors that might alter the results are the dental chair level, height of operator or presence of dental loupes compelling the dentist to remain at distance. It is worth considering the direction of splatter while operating. Dahlke et al. (2012) in an invitro study reported that the position of the handpiece and the working dental arch impacts volume and direction of splatter. As the water is ejected and closer to the upper anterior teeth, it is presumable that there is escape of water from the mouth rather than it binding to the oral surfaces or the rubber dam. For tooth #11, circumferential preparation of the tooth would naturally direct the source of splatter north of the patient and partially away from the operator who's at a lateral position. With EOS, a reduced amount of aerosol generation was still accounted for. As for posterior tooth preparation #16, aerosols are partly confined within the oral cavity and hence less contamination.

As stated previously, the primary objective was to measure the intensity of aerosols within the specified allocations and the secondary objective was to appreciate the prevention required to minimize the consequence of transmission. The significance lies in the plotted aerosols on the UIP, the red value. With regards to the primary criterion, the highest intensity of red was seen 30cm behind the manikin's head – without EOS. The highest mean(SD) value for blue and lowest mean(SD) value for red was seen on the operators face-shield – without EOS. With regards to the secondary criterion, these results are not correlated to the values seen with EOS. Because if the mean(SD) value was originally low, subsequently with the presence of EOS, it would be lower. Therefore, it is ideal to measure the highest difference (i.e.; value of mean(SD) red value without EOS minus the mean(SD) red value with EOS) to identify where the purpose of EOS deems favorable. The highest difference was observed in the operator's chest in both #11 and #16 tooth preparations. A comparable study by Yang et al. (2021), simulated an experiment by operating in the oral cavity without drilling tooth structure for 6 minutes and concluded that the extra oral suction can reduce aerosol dispersion at the operator's chest to a baseline level. This indicates the positive efficacy in using EOS and its relative safety for the operator.

It is worth mentioning the positioning of the collecting cone and its influence on the readings. The proximity and the position of the funnel shaped tip of the extra oral suction unit play a significant role in competence. In this study, the cone was positioned at 5 ± 1 inches perpendicularly from the phantoms head for both anterior and posterior tooth drilling whereas in the study by Shahdad et al. (2020) it was positioned at 5 o'clock and 6 – 8 inches from the oral cavity. A study by Horsophonphong et al. (2021), concluded that the drilling side and the corresponding location to be the standard position and when placed at an anterior-perpendicular position (6 o'clock) or laterally (5-7 o'clock), there was a significant reduction in operator contamination compared to high-volume evacuation. The ergonomic design and its flexibility allows the operator to work without any visual or practical obstruction and its efficacy is relative to the procedural site and the type of procedure conducted. During the pandemic, extraoral suctions have brought on high volume of attention and wide recognition to dentists and the market. The device's framework varies in performance due to trademark but carries out the same conventional function. Aerosols and droplets generated from the oral cavity are instantly vacuumed into the system where a high efficiency particulate air (HEPA) filter and ultraviolet light aid in disinfection. Other than its vacuum power, the EOS also reduces the need for additional assistants and further exposure to potential viral infection.

As per Doremalen et al. (2020), SARS-CoV-2 can persist in aerosols for up to 3 hours. The dental mucosa and the oral cavity act as a reservoir for opportunistic viruses especially those associated with respiratory diseases such as those manifested in COVID-19. The oral cavity harbors multiple pathogens with the potential of infecting oral healthcare workers during aerosol generating procedures (Zemouri et al., 2017). Inevitably, patients will exhale during treatment extruding all forms of aerosols whether it is SARS-CoV-2 or not. Due to the narrow diameter provided by the low volume and high-volume suction, it will not be sufficient to suppress the cloud of aerosols produced. The extra oral suction has the advantage of continuously eliminating the aerosols over a larger surface area at the collection cone directly from the source. Extra oral suction devices have also shown to decrease blood-contaminated aerosols suspended in the air at 0.5m and 1m from the oral cavity (Bentley et al., 1994). One conclusive drawback of using EOS is the increasingly strident noise generated from the device. This can cause an unpleasant ambience for both the operator and the patient affecting quality of work. However, the EOS delivers benefits that outweigh these drawbacks. Ultimately, the EOS represent feasibility in reducing aerosol transmission particularly in high aerosol generating procedures such as restorative preparation but do not completely eradicate the risk.

Rubber dam isolation acts as a primary method of protection in limiting aerosol dissemination and reducing contamination. It is crucial for adhesive dentistry to contain moisture control but not as common for restorative tooth preparation as the soft tissue is impinged and visualizing the finish line is compromised. This study did not implement rubber dam isolation for convenience purposes and to compare with a "worst case scenario" situation. Gilbert et al. (2010) found that most dentists (63%) did not use a rubber dam for any restoration, while (33%) stated that the rubber dam isolation is too slow for use in a busy practice. However, in view of the COVID-19 pandemic, rubber dam isolation is being highly acknowledged as one of many mitigation strategies to reduce infective aerosol particles in the operatory field. Multiple studies such as those by Shahdad et al. (2020) and Nejatianesh et al. (2013) reported that rubber dam led to a significant decrease of contaminated sites with and without EOS. Hence, it's application limits the source of contamination and splatter produced for oral healthcare professionals. However, another study by Al-Amad et al. (2017) during posterior cavity preparation found that the surface of the rubber dam increased the size of the particulate expelled and contaminated head scarfs. In this study, the operator was wearing a head cap but no UIP was allocated to visualize aerosol contamination. Evidence published about rubber dam practice and their effectiveness in aerosol generating procedures needs additional investigation.

COVID-19 has brought to the forefront the use of personal protective equipment (PPE) in dental practices and thus, an evolution regarding its use in dentistry (Sharma 2021). The secondary outcome in this study was to understand the level of protection required against aerosol generating procedures to protect the dental team and patients from infection transmission. The results outlined the high and low risk exposure sites by ranking 30cm behind the manikin's head as the worst contaminated site followed by the operator’s chest then the simulated assistant’s chest and finally the operator’s face-shield. This was consistent with findings of other investigations highlighting the approach of personal protective equipment necessary, for the operator and the assistant. The long sleeved non-woven isolation gown serves a simple yet effective role in minimizing exposure risk to the arms and chest for the dental operatory team. None of the COVID-19 guidelines suggest PPE for patients, however cross-contamination is likely during aerosol generating procedures and it would establish bilateral security and comfort between the clinician and assistant. As data proclaims, aerosols remain suspended in the surrounding and therefore it is advisable to avoid removing PPE directly after the procedure is completed until air exchanges have been finalized. The face-shield contributed immense protection against spatters and in preventing eye contamination especially against treating asymptomatic carriers. It acts as an effective barrier to reduce viral load on the mask surface and respirators confirming the significance of their collective use. As per Meng et al. (2020), in dental practice, especially during the COVID-19 pandemic, face shields are highly recommended when aerosol-generating procedures are performed. The N95 masks were found to be 95% effective in filtering particles as small as 0.3μm (Qian et al., 1998). The respirator masks were not used in this study, however have been presumed to provide ultimate protection during aerosol generating procedures against respiratory infections. High, filtering capacity respirator masks are manufactured to filter over 90% of virus-size contaminants, offering the best protection in a dental clinic (Li et al., 2020). With constant conflict on the fundamental protection needed, Bovin (2015) highlighted the reasons that can lead to inappropriate use and further cross contamination which include lack of awareness, donning and doffing time consumption, and improper and unsafe removal of the PPE.

6.1 Limitations and future research

Several limitations need to be addressed in our invitro study. Firstly, and most predominantly, the study was a simulation and patient factors such as saliva, blood, soft tissues, breathing, patient compliance, coughing and interaction were not accounted for. These factors would potentially have had an influence on the results. Saliva's role is of primary concern as it embodies pathogens and acts as a crucial risk factor in transmission. In this study, tooth drilling was performed for 15 minutes it has been estimated that over a 15-minute exposure with high-speed instruments, places the operator at an exposed risk of 0.014-0.12 µL of saliva (Bennett et al., 2000). A study by To et al. (2020) found that saliva belonging to SARS-CoV-2 infected patients estimated the viral load at 3.3×10^6 copies per mL. Therefore, without PPE and within 0.5m distance, the operator is exposed to 46-396 viral load copies throughout the 15-minutes procedure. The viscosity of saliva is higher than water and it would be of interest to explore the difference and effect on aerosol generation rate. Another limitation was the overestimation in the size of particles spread.

When the citric acid (10%) was ejected from the waterline onto the UIP, the filter paper absorbed the acid and spread out generating a wider rim than expected. Additionally, the uncontaminated UIP (blue) sites might consist of red components which could or could not have been picked up by the software. In this study, the clinician remained in the most common operating position at 9 o'clock. This is unnatural as it is acknowledged that dentists and assistants will undertake several positions throughout depending on the procedure, tooth number, clinical experience and operating conditions. In this experimental setup, the assistant was simulated as a stand. The absence of assistant maneuver would impact aerosol transmission as the assistant would keep track and contain the aerosols carefully. Therefore, mitigating factors such as four-handed dentistry, rubber dam and high volume suction were not used. The water flow rate for the high-speed handpiece used in the simulated lab ranged from 12-14 mL/min. This flow rate could be increased to greater than 30 mL/min (Yang et al., 2013) for a real-life clinical practice setting.

7. CONCLUSION

Within the limitations of this present study, the following conclusions were drawn:

1. SARS-CoV-2 coronavirus has emphasized the significance of aerosol management and its relative safety protocols.
2. Geriodontic dentistry is mainly accommodated by prosthodontists and it is important to appreciate the risks and benefits in each potential restorative treatment.
3. This study established another method to detect aerosol contamination generated by restorative prosthetic crown procedures as it remains a major threat throughout the pandemic.
4. Extra oral suction proved highly efficient in reducing aerosol transmission during treatment, allowing a safer environment for the patient and the dental staff.
5. Contamination levels were detected on all allocated sites emphasizing the importance of PPE such as surgical disposable gowns, masks and face-shields.
6. This study may provide the basis for prosthodontists to enrich their experience in infection control and safe practice

8. REFERENCES

1. Ahmed MA, Jouhar R. Dissemination of Aerosol and Splatter in Clinical Environment during cavity preparation: An In Vitro Study. Int J Environ Res Public Health 2021; 18(7): 3773
2. Al-Amad S., Awad M., Edher F., Shahramian K., Omran T. The effect of rubber dam on atmospheric bacterial aerosols during restorative dentistry. J. Infect. Public Health. 2017; 10:195–200
3. Alduwayhi S, Shaikh SA, Thakare AA, Mustafa MZ, Mallineni SK. Remote management of prosthodontic emergencies in geriatric population during the pandemic outbreak of COVID-19. Front Med. 2021: 8:648675
4. Allison JR. et al. Evaluating aerosol and splatter following dental procedures: Addressing new challenges for oral health care and rehabilitation. J Oral Rehabil 2021; 48(1): 61-72
5. Barabari P, Moharamzadeh K. Novel Coronavirus (COVID-19) and Dentistry – A Comprehensive Review of Literature. Dent J 2020; 8 (2):53
6. Bennett AM, Fulford MR, Walker JT, Bradshaw DJ, Martin MV, Marsh PD. Microbial aerosols in general practice. Brit Dent J 2000; 189(12): 664-667
7. Bentley CD, Burkhart NW, Crawford JJ. Evaluating spatter and aerosol contamination during dental procedures. J Am Assoc 1994; 125: 579-584
8. Benzian H, Beltrán-Aguilar E, Niederman R. Systemic Management of Pandemic Risks in Dental Practice: A Consolidated Framework for COVID-19 Control in Dentistry. Front Med (Lausanne). 2021; 8:644515
9. Bernghi L, Barenghi A, Garagiola U, Di Blasio A, Gianni AB, Spadari F. Pros and cons of CAD/CAM technology for infection prevention in dental settings during COVID-19 outbreak. Sensors (Basel) 2021; 22(1):49

10. Beyerstedt S, Casaro EB, Rangel EB. COVID-19: angiotensin-converting enzyme 2 (ACE2) expression and tissue susceptibility to SARS-CoV-2 infection. Eur J clin Microbiol Infect Dis 2021; 40(5); 905-919
11. Bilhan H, Erdogan O, Ergin S, Celik M, Ates G, Geckili O. Complication rates and patient satisfaction with removable dentures. J Adv Prosthodont. 2012;4(2):109-115.
12. Bloom I, Lawrence W, Barker M, Baird J., et al. What influences diet quality in older people? A qualitative study among community-dwelling older adults from the Hertfordshire Cohort study, UK. Public Health Nutr. 2017; 20:2685-2693
13. Bovin J, PPE used incorrectly half the time. Health Leaders; 2015
14. Chen XC, Ding JF, Xu DH, Caj ZG, Li XE, Shi ZD, et al. Preventive and control measures for the coronavirus pandemic in clinical dentistry. Chin J Dent Res. 2020; 23:99-104
15. Clare C. Cross contamination control in prosthodontic practice, Int J Prosthodont 1991; 4:337-34
16. Dadnam D, Dadnam C, Al-Saffar H. Pandemic bruxism. Br Dent J. 2021; 230(5):27
17. Dalhke WO, Cottam MR, Herring MC, Leavitt JM, Ditmyer MM, Walker RS. Evaluation of the spatter-reduction effectiveness of two dry-field isolation techniques. J Am Dent Assoc 2012; 143: 1199-204
18. Dhand R, Li J. Coughs and Sneezes: Their Role in Transmission of Respiratory Viral Infections, Including SARS-CoV-2. Am J Respir Crit Care Med. 2020;202(5):651-659
19. Doremalen N, Bushmaker T. Aerosol and surface stability of SARS-CoV-2 compared with SARS-CoV-1. N Engl J Med 2020; NEJMc 2004973

20. Gilbert GH, Litaker MS, Pihlstorm DJ, et al. Rubber dam use during routine operative dentistry procedures: findings from the Dental PBRN. Oper Dent 2010; 35(5):491-49
21. Guan W, Liang W, Zhao Y. Comorbidity and its impact on 1590 patients with COVID-19 in China: a nationwide analysis. Eur Respir 2020; 55 (5): 2000547
22. Hackney R.W., JR., Crawford J.J., Tulis J.J. Using a biological indicator to detect potential sources of cross-contamination in the dental operatory. JADA. 1998; 129(11):1567-1577
23. Haleem A, Javaid M, Pratap R, Suman SR. Telemedicine for healthcare: Capabilities, features, barriers, applications. Sensors International 2021; (2); 100117
24. Harrel S, Molinari J. Aerosols and splatter in dentistry – A brief review of the literature and infection control implications. J Am Dent Assoc 2004; 135(4): 429-437
25. Harrel SK, Barnes JB, Rivera-Hidalgo F. Aerosol and splatter contamination from the operative site during ultrasonic scaling. JADA. 1998; 129:1241–1249
26. Hinds WC. Aerosol technology: Properties, behavior, and measurement of airborne particles. New York Wiley 1982: 6-8
27. Horsophonphong S, Chestsuttayangkul Y, Surarit R, Lertsooksawat W. Efficiacy of extraoral suction devices in aerosol and splatter reduction during ultrasonic scaling: A laboratory investigation. J Dent Res Dent Clin Dent Prospects 2021; 15; 197-202
28. Infection Prevention and Control of Epidemic- and Pandemic-Prone Acute Respiratory Infections in Health Care. Geneva: World Health Organization; 2014. 4

29. Ionescu AC, Cagetti MG, Ferracane JL, Godoy FG. Topographic aspects of airborne contamination caused by the use of dental handpieces in the operative environment. J Am Dent Assoc 2020; 151(9): 660-667
30. Ishihama K. et al. Evidence of aerosolized floating blood mist during oral surgery. J Hosp Infect 2009; 71(4): 359-64
31. Jain M, Mathur A, Mathur A, Mukhi PU, Ahire M, Pingal C. Qualitative and quantitative analysis of bacterial aerosols in dental clinical settings: risk exposure towards dentist, auxiliary staff, and patients. Journal of Family Medicine and Primary Care 2020; 9(2):1003-8
32. Jarvis MC. Aerosol Transmission of SARS-CoV-2: Physical Principles and Implications. Front Public Health. 2020; 8:590041.
33. Jefferson T, Del Mar CB, Dooley L, Ferroni E, Al-Ansary LA, Bawazeer GA, et al. Physical intervention to interrupt and reduce the spread of respiratory viruses: a Cochrane review. Health Technol Assess. 2010; 14: 347-476
34. Karia R, Gupta I, Khandait H, Yadav A. COVID-19 and its Modes of Transmission. SN Compr Clin Med 2020; 1:1-4
35. Kleinstein S., Nelson K., Freire M. Inflammatory Networks Linking Oral Microbiome with Systemic Health and Disease. J. Dent. Res. 2020; 99:1131–1139.
36. L Meng, Hua F, Bian Z. Coronavirus disease 2019 (COVID-19): emerging and future challenges for dental and oral medicine. J Dent Res 2020; 99(5): 481-487
37. Li DTS, Samaranayake LP, Leung YY, Neelakantan P. Facial protection in the era of COVID-19: a narrative review. Oral Dis 2020; 3: 665-673

38. Micik RE, Miller RL, Mazzarella MA, Ryge G. Studies on dental aerobiology, I: bacterial aerosols generated during dental procedures. J Dent Res 1969; 48(1): 49-56
39. Miller R.L., Micik R.E, Abel C., Ryge G. Studies on dental aerobiology, II: microbial discharged from the oral cavity of dental patients. J Dent Res. 1971; 50(3): 621-625
40. Monarca S, Grottolo M, Renzi D, Paganelli C, Sapelli P, Zerbini I, et al. Evaluation of environmental bacterial contamination and procedures to control cross infection in a sample of Italian dental surgeries. Occupational and Environmental Medicine 2000; 57(11):721-6
41. Murray JP, Slack GL. Some sources of bacterial contamination in everyday dental practice. Br Dent J 1957; 134: 172-174
42. Nejatidanesh F, Khosravi Z, Goroohi H, Badrian H, Savabi O. Risk of contamination of different areas of dentist's face during dental practice. Int J Prev Med 2013; 4; 611-615
43. Nobrega MRT. et al, Aerosol generated by dental procedures: A scoping review. J Evidence Based Med. 2021; (14) 4; 303-312
44. Nulty A, Lefkaditis C, Zachrisson P. A clinical study measuring dental aerosols with and without a high-volume extraction device. Br Dent J 2020
45. Papi P, Murro BD, Penna D, Pompa G. Digitial prosthetic workflow during COVID-19 pandemic to limit infection risk in dental practice. Oral Dis 2021; 3;723-726
46. Park M, Cook AR, Lim JT, Sun Y, Dickens BL. A systematic review of COVID-19 epidemiology based on current evidence. J Clin Med 2020; 9(4) 967

47. Passarelli PC, Rella E, Manicone PF. The impact of the COVID-19 infection in dentistry. Experimental Biology and Medicine 2020; 245(11): 940-944

48. Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zembic A. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clin Oral Implants Res. 2012;23(Suppl 6):22–38

49. Polednik B. Aerosol and bioaerosol particles in a dental office. Environmental Research 2014; 134:405-9.

50. Qian Y, Willeke K, Grinshpun SA, Donnelly J, Coffey CC. Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles. Am Ind Hyg Assoc J 1998; 59(2):128-32

51. Rautemaa R, Nordberg A, Wuolijoki-Saaristo K, Meurman J. Bacterial aerosols in dental practice – a potential hospital infection problem? Journal of Hospital Infection 2006; 64(1):76-81

52. Seo JY, Lee ST, Choi SY, Kim JW, Kwon TG. Experience of patients diagnosed as asymptomatic COVID-19 after dental treatment. Maxillofac Plast Reconstr Surg. 2021;43(1):30

53. Shahdad S, Patel T, Hindocha A. The efficacy of an extraoral scavenging device on reduction of splatter contamination during dental aeorosl generating procedures: an exploratory study. Br Dent J 2020

54. Shamszadeh S, Parhizkar A, Mardani M, Asgary S. Dental considerations after the outbreak of 2019 Novel Coronavirus Disease: A Review of Literature. Arch Clin Infect Dis 2020; 15(2): e103257

55. Sharma P. Personal Protective Equipment. Bdj in Practice; 2021; 34(3): 38

56. Sotiriou M, Ferguson SF, Davey M, Wolfson JM. Et al, Measurement of particle concentrations in a dental office. Environ Monit Assess 2008; 137(1-3):351-61
57. Spagnolo AM, Sartini M, Cristina ML. Microbial Contamination of Dental Unit Waterlines and Potential Risk of Infection: A Narrative Review. Pathogens. 2020 ;9(8):651
58. Thoma DS, Sailer I., et al. A systematic review of the survival and complication rates of resin-bonded fixed dental prostheses after a mean observation period of at least 5 years. Clin Oral Implants Res 2017; (11); 1421-1432
59. To KK-W, Tsang OT-Y, Yip CC-Y, et al. Novel Coronavirus in Saliva. Clin Infect Dis 2020; 71: 841-843
60. Tonkaboni A, Amirzade-Iranaq MH, Ziaej H, Ather A. Impact of COVID-19 on Dentistry. Advances in experimental medicine and biology 2021; 1319: 623-636
61. Veena HR, Mahantesha S, Joseph PA, Patil SR, Patil SH. Dissemination of aerosol and splatter during ultrasonic scaling: a pilot study. J Infect Public Health 2015; 8(3): 260-5
62. Vernon JJ, Black EVI, Dennis T, Devine DA, Fletcher L, Wood DJ, Nattress BR. Dental Mitigation Strategies to Reduce Aerosolization of SARS-CoV-2. J Dent Res 2021; 100(13) 1461-1467
63. Vuorinen V, Aarnio Mia, Alava M. Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors. Safety science 2020; (13); 104866
64. Yamada H. et al. Ariel dispersal of blood-contaminated aerosols during dental procedures. Quintessence Int 2011; 42: 399-405

65. Yang W-J, et al. Effect of the spray pattern, water flow rate, and cutting position on the cutting efficiency of high-speed dental handpieces. Int J Prosthodont 2013; 26(1): 85-7
66. Yang, M., Chaghtai, A., Melendez, M. et al. Mitigating saliva aerosol contamination in a dental school clinic. BMC Oral Health 2021 (21); 52
67. Yoshinaga L. The use of teledentistry for remote learning applications. Pract Proced Aesthet Dent 2001; 13: 327-328
68. Zemouri C, Johnannes S, Wim C, Laheji A. A scoping review on bio-aerosols in healthcare and the dental environment. PLOS ONE 2017; 12; e0178007
69. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult patients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet 2020; 1054-1062