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Environmental Health and Safety in Dental Clinics in the eastern province of Saudi Arabia

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Abstract:

Dental practices have evolved over time, introducing standardized safety protocols and enhancing safety standards. Regulatory bodies like OSHA, CDC, and ADA have set standards for infection control, chemical safety, and occupational health. Dental clinics face biological, chemical, and physical hazards. Maintaining high standards of EHS is crucial for patient and professional health, regulatory compliance, patient trust, and environmental sustainability. The COVID-19 pandemic has necessitated extra precautionary measures, and infection control measures have improved. Patients generally accept dental-dams and ergonomic interventions for infection control and safety.

The aim of this study is to evaluate and enhance the environmental health and safety (EHS) protocols within dental clinics by examining key parameters that influence the well-being of both patients and dental professionals. Specifically, the study will focus on assessing air quality, infection control compliance, and the presence of isolated microorganisms in the workplace during invasive dental procedures.

This study aims to assess environmental health and safety (EHS) parameters in dental clinics using a cross-sectional observational design. Participants include dental professionals and patients, who will evaluate infection control compliance and provide insights. Data will be collected from ten hospitals in Saudi Arabia, focusing on air quality, infection control compliance, and the presence of isolated microorganisms during invasive dental procedures.

The study found that dental clinics have high concentrations of PM2.5 and CO2 in treatment rooms, indicating dental procedures. However, higher levels in waiting rooms suggest potential ventilation issues. Adherence to infection control protocols varied among dental professionals, with hand hygiene practices more prevalent among dental assistants. The study also highlighted the need for effective air filtration and control measures.

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The study on environmental health and safety in dental clinics reveals critical parameters affecting safety and quality. It highlights air quality, infection control compliance, and microbial contamination, emphasizing the need for high standards and effective cleaning and disinfection.

Keywords: Environmental Health, Air quality, Safety, Infection prevention, Sterilization techniques.

Introduction:

The field of dentistry, while primarily focused on oral health, intersects significantly with environmental health and safety (EHS). Understanding the background of EHS in dental clinics involves examining the evolution of dental practices, the emergence of regulatory frameworks, and the identification of key hazards that dental professionals and patients face. [1]

Historically, dental practices have evolved from rudimentary procedures to highly specialized and technologically advanced treatments. This evolution has brought about significant improvements in patient care but has also introduced complex EHS challenges. Early dental practices lacked standardized safety protocols, leading to higher risks of infection, cross-contamination, and occupational hazards. Over time, the development of sterilization techniques, the introduction of PPE, and advances in dental materials have significantly enhanced safety standards. [2]

The establishment of regulatory bodies and the development of guidelines have played a crucial role in shaping EHS in dental clinics. Agencies such as the Occupational Safety and Health Administration (OSHA), the Centers for Disease Control and Prevention (CDC), and the American Dental Association (ADA) have been instrumental in setting standards for infection control, chemical safety, and occupational health. Key regulations include the Bloodborne Pathogens Standard (OSHA), which mandates protocols to protect healthcare workers from exposure to bloodborne pathogens, the CDC's Guidelines for Infection Control in Dental Health-Care Settings, which provides comprehensive recommendations for infection prevention and control, and OSHA's Hazard Communication Standard, which ensures that information about chemical hazards is available and understandable to workers. [3]

Dental clinics face a variety of hazards that can impact both practitioners and patients. These hazards can be categorized into biological, chemical, and physical risks. Biological hazards

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include the risk of transmission of infectious diseases through exposure to blood, saliva, and other bodily fluids, making effective sterilization of instruments, proper use of PPE, and adherence to infection control protocols essential. Chemical hazards arise from the use of various substances such as disinfectants, anesthetics, and dental materials, where improper handling and exposure can lead to health issues like respiratory problems, skin irritation, and long-term effects from chronic exposure. Physical hazards encompass risks such as musculoskeletal disorders due to repetitive motions and awkward postures, radiation exposure from dental imaging equipment, and injuries from sharp instruments, necessitating ergonomic workplace design, appropriate training, and protective measures. [4]

Maintaining high standards of EHS in dental clinics is essential for several reasons. It protects the health of both patients and dental professionals by minimizing the risk of infections, chemical exposures, and physical injuries. It also ensures regulatory compliance, adhering to established guidelines and regulations to avoid legal repercussions and ensure a safe working environment. Furthermore, a strong commitment to safety and hygiene enhances patient trust and satisfaction. Finally, implementing environmentally friendly practices, such as reducing waste and conserving resources, contributes to overall public health and sustainability. [5]

The COVID-19 pandemic has necessitated extra precautionary measures in dental clinics to prevent virus transmission. Dental clinics in Fiji, for example, have adopted behavioral preventative strategies to mitigate the risk of infection. Similarly, pediatric dentists in Germany have adapted their practices to continue providing care during lockdowns, which is crucial for unvaccinated children. [6]

Infection control remains a priority, with significant improvements observed in infection control measures and occupational safety following health education program interventions in dental clinics. Moreover, safety rounds have been implemented in Clalit Smile dental clinics to promote patient safety, effectively identifying risks and systemic shortcomings. [7, 8]

The use of dental-dams (DD) during endodontic procedures is generally accepted by patients for infection control and safety, with many expressing a preference for its continued use. Additionally, ergonomic interventions have been recommended to reduce musculoskeletal

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disorder symptoms among orthodontists in the Philippines, highlighting the need for ergonomic workstations and task modifications. [9]

Aim of the study

The aim of this study is to evaluate and enhance the environmental health and safety (EHS) protocols within dental clinics by examining key parameters that influence the well-being of both patients and dental professionals. Specifically, the study will focus on assessing air quality, infection control compliance, and the presence of isolated microorganisms in the workplace during invasive dental procedures.

Importance of Research

Enhancing Patient and Practitioner Safety

One of the foremost reasons for conducting this research is to enhance the safety of both patients and dental professionals. Dental procedures often involve exposure to various biological, chemical, and physical hazards. By assessing air quality parameters such as PM2.5 and CO2 levels, the study aims to ensure a safer breathing environment within dental clinics. High levels of PM2.5 can lead to respiratory issues and other health complications, while elevated CO2 levels can indicate poor ventilation, affecting cognitive function and overall comfort. Improved air quality directly contributes to a healthier and safer clinical environment.

Improving Infection Control

Infection control is a cornerstone of safe dental practice. This research aims to evaluate compliance with infection control protocols, identifying gaps and areas for improvement. Effective infection control measures are essential in preventing the transmission of infectious diseases, protecting both patients and dental staff from potential health risks. By ensuring rigorous adherence to these protocols, the study can help reduce the incidence of healthcare-associated infections, thereby enhancing patient outcomes and workplace safety.

Identifying and Mitigating Microbial Risks

Invasive dental procedures can generate aerosols and splatters that carry potentially harmful microorganisms. This research will identify and characterize the microorganisms present

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in the dental workplace, particularly during these procedures. Understanding the microbial landscape within dental clinics is crucial for developing targeted strategies to mitigate the risks of infection. This knowledge can lead to the implementation of more effective sterilization practices, improved use of personal protective equipment (PPE), and better overall infection control measures.

Regulatory Compliance and Best Practices

The research findings can also support dental clinics in achieving and maintaining compliance with regulatory standards. Regulatory bodies such as the Occupational Safety and Health Administration (OSHA) and the Centers for Disease Control and Prevention (CDC) set guidelines to ensure the safety of healthcare environments. By adhering to these standards, dental clinics can avoid legal repercussions and foster a culture of safety. Additionally, the study's insights can inform best practices, contributing to the continuous improvement of EHS protocols in dental settings.

Promoting Sustainable Practices

Environmental sustainability is an increasingly important consideration in healthcare. This research can highlight areas where dental clinics can adopt more sustainable practices, such as reducing waste, improving energy efficiency, and using environmentally friendly materials. Sustainable practices not only benefit the environment but also enhance the overall health and well-being of the community.

Contributing to Public Health

Ultimately, the research contributes to broader public health goals by ensuring that dental clinics operate safely and efficiently. By protecting the health of patients and dental professionals, the study supports a healthier population. Furthermore, by addressing environmental and infection control concerns, the research can help prevent the spread of infectious diseases, contributing to public health at large.

Problems and Research Questions

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Poor Air Quality in Dental Clinics: Dental procedures often generate aerosols that can contain particulate matter (PM2.5) and other contaminants. Elevated levels of PM2.5 and CO2 in dental clinics can pose significant health risks to both patients and dental professionals, potentially leading to respiratory problems, reduced cognitive function, and overall discomfort.

Non-Compliance with Infection Control Protocols: Despite established guidelines for infection control, there may be gaps in adherence within dental clinics. Non-compliance with these protocols can increase the risk of cross-contamination and transmission of infectious diseases, compromising the safety of both patients and dental staff.

Presence of Harmful Microorganisms During Invasive Procedures: Invasive dental procedures can produce aerosols and splatters that carry potentially harmful microorganisms. Identifying and mitigating these microbial risks is essential to prevent infections and ensure a safe clinical environment.

Research Questions

Air Quality Assessment: The study aims to address several key questions regarding air quality in dental clinics. What are the levels of particulate matter (PM2.5) in dental clinics during and after various dental procedures? How do CO2 levels vary in dental clinics, and what does this indicate about ventilation efficiency and indoor air quality? By answering these questions, the study will provide valuable insights into the current state of air quality in dental settings and identify areas for improvement to ensure a safer breathing environment.

Infection Control Compliance: To understand and enhance infection control in dental clinics, the study will explore the extent to which dental clinics comply with established infection control protocols. It will also investigate the most common areas of non-compliance and suggest practical measures to improve adherence to these protocols. Key research questions include: To what extent do dental clinics comply with established infection control protocols? What are the most common areas of non-compliance in infection control within dental clinics? How can adherence to infection control protocols be improved to enhance safety?

Microbial Risks in Dental Clinics: The study will focus on identifying and characterizing microorganisms present in dental clinics, particularly during invasive procedures. Research

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questions include: What types of microorganisms are isolated in dental clinics, particularly around the workplace during invasive procedures? How do these microorganisms vary in different areas of the clinic and during different procedures? What strategies can be implemented to reduce the presence and impact of harmful microorganisms in dental settings? By answering these questions, the study aims to develop targeted strategies to minimize microbial risks and improve overall infection control measures.

Methodology

Participants

The participants in this study will include dental professionals (dentists, dental hygienists, dental assistants) and patients from multiple dental clinics. Dental professionals will be involved in evaluating infection control compliance and providing insights into daily practices and challenges. Patients visiting these clinics during the study period will indirectly participate through environmental sampling and air quality monitoring conducted during their appointments.

Study Design

This study will employ a cross-sectional observational design to assess environmental health and safety (EHS) parameters in dental clinics. Data will be collected from multiple dental clinics to ensure a comprehensive evaluation of EHS practices across different settings. The study will focus on three main areas: air quality (PM2.5 and CO2 levels), infection control compliance, and the presence of isolated microorganisms during invasive dental procedures.

Data Collection

Air Quality Assessment:

Air quality monitors will be installed in treatment rooms to continuously measure PM2.5 and CO2 levels during dental procedures. Data will be collected before, during, and after procedures to capture variations in air quality.

Infection Control Compliance:

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Observational Checklists: Trained observers will use standardized checklists to assess compliance with infection control protocols. Key areas of observation will include the use of PPE, sterilization of instruments, hand hygiene practices, and waste management.

Self-Reported Surveys: Dental professionals will complete surveys to provide additional insights into their infection control practices and any challenges they face in adhering to protocols.

Microbial Sampling:

Surface Swabs: Swabs will be taken from various surfaces in treatment rooms before and after invasive procedures to identify and quantify microorganisms.

Air Sampling: Air samples will be collected during procedures to detect airborne microorganisms.

Culture and Identification: Collected samples will be cultured in a laboratory to isolate and identify microorganisms. Molecular techniques such as PCR may be used for further identification and characterization.

Data for this study are collected from ten hospitals and medical centers located in the Eastern Province of Saudi Arabia, namely:

1. King Fahd Hospital of the University (Al Khobar)
2. Saudi Aramco Medical Services Organization Hospital (Dhahran)
3. King Fahd Military Medical Complex (Dhahran)
4. Almana General Hospitals (Dammam)
5. Dammam Medical Complex (Dammam)
6. King Fahd Specialist Hospital (Dammam)
7. Al Mouwasat Hospital (Al Jubail)
8. Almana Hospital (Al Khobar)
9. Dr. Soliman Fakeeh Hospital (Al Khobar)
10. National Guard Health Affairs – NGHA, Saudi Arabia

Research Time Domain:

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The study will be conducted over a period of six months. This timeframe will allow for the collection of sufficient data across different dental clinics and ensure seasonal variations in air quality and infection control practices are accounted for.

Research Tools:

Air Quality Monitors: Devices capable of continuously measuring PM2.5 and CO2 levels, with data logging capabilities for detailed analysis.

Observational Checklists and Surveys: Standardized tools developed based on established infection control guidelines to ensure consistent and reliable data collection.

Microbial Sampling Kits: Sterile swabs, air samplers, and transport media for collecting and preserving microbial samples from surfaces and air.

Laboratory Equipment: Culture media, incubators, and molecular biology tools (e.g., PCR) for isolating, identifying, and characterizing microorganisms.

Statistical analysis

The results obtained by the researchers will be displayed and analyzed, Data were fed to the pc and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). We will display the arithmetic means of the questionnaire responses obtained from the sample and present the standard deviations to identify the degree of variation in those responses through displaying the frequencies and their percentages to identify the level of responses about the variables.

Results

Table 1: Air Quality Assessment in Dental Clinics: Comparative Analysis of Particulate Matter and Carbon Dioxide Levels in Treatment and Waiting Areas

Group Parameter	Clinic	Waiting Room	limit	P-value
Particulate matter 2.5 µg/m^3	24 ± 4	10 ± 5	[C]25 according to World Health Organization (WHO)	<0.0001
CO2, ppm	771 ± 54	935 ± 85	1000 according to ASHRAE, Standard 62.1-2016 for the	<0.0001

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			Ventilation for Acceptable Indoor Air Quality	

The study's findings on air quality parameters in dental clinics reveal significant differences in particulate matter (PM2.5) and carbon dioxide (CO2) levels between clinic treatment rooms and waiting areas, both of which have implications for environmental health and safety standards.

Particulate Matter (PM2.5)

The average concentration of PM2.5 in clinic treatment rooms was found to be 24 ± 4 $\mu g/m^3$, whereas in the waiting rooms, it was significantly lower at 10 ± 5 $\mu g/m^3$. According to the World Health Organization (WHO), the recommended limit for PM2.5 is 25 $\mu g/m^3$. The PM2.5 levels in treatment rooms are close to this threshold, indicating that dental procedures contribute significantly to particulate matter levels. The lower levels in waiting rooms suggest that these areas are less affected by procedural activities, possibly due to their distance from the sources of particulate generation or better ventilation. The P-value of <0.0001 indicates that the difference in PM2.5 levels between treatment rooms and waiting rooms is statistically significant, highlighting the need for improved air quality management in treatment areas.

Carbon Dioxide (CO2)

The study found that the average CO2 concentration in clinic treatment rooms was 771 ± 54 ppm, while in the waiting rooms, it was higher at 935 ± 85 ppm. Both values are below the limit of 1000 ppm set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2016 for acceptable indoor air quality. However, the higher CO2 levels in waiting rooms suggest potential issues with ventilation, as elevated CO2 can be a marker of inadequate air exchange. The P-value of <0.0001 signifies a statistically significant difference in CO2 levels between treatment rooms and waiting rooms. This finding underscores the importance of ensuring adequate ventilation not only in treatment areas but also in waiting rooms to maintain acceptable air quality standards.

Table 2: Adherence to Infection Control Protocols Among Dental Professionals: A Comparative Analysis of Practices Among Female Dentists, Male Dentists, and Dental Assistants

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Group Parameter	Female Dentists	Male Dentists	Dental Assistants
Hand jewelry (finger rings)	63.5	43.5	80.7
Correct hand hygiene before dental work	40	30.4	5.9
Wearing gloves during dental work	100	100	100
Removing gloves between different activities	85.9	100	72.6
Hand disinfection after removing gloves	32.5	39.5	7
Wearing masks during dental work	100	100	84.9
Wearing goggles during dental work	77.6	100	74.5
Changing clothes after visible contamination	100	100	100
Correct handling of sterile instruments	100	100	81.3
Using rubber dams→ aseptic operation field	15.2	30	-
Recapping of needles	11.6	0	12.5
Safe disposal of sharps	92.6	100	90.6

The data on infection control practices among different dental professional groups—female dentists, male dentists, and dental assistants—reveals varied adherence to key infection control protocols. Understanding these differences is essential for improving overall safety and ensuring consistent practices across all roles within the dental clinic.

The study focuses on the hand hygiene practices of dental assistants, female dentists, and dental assistants. Hand jewelry was reported more frequently among dental assistants (80.7%) than female dentists (63.5%) and male dentists (43.5%), which can interfere with proper hand hygiene and increase the risk of cross-contamination. Female dentists (40%) were found to practice correct hand hygiene before dental work, while dental assistants (5.9%) showed lower adherence.

All groups reported 100% adherence to wearing gloves during dental work, indicating a strong understanding of the importance of gloves in preventing cross-contamination and protecting patients and practitioners. However, there is a notable difference in adherence to glove removal between different activities, with female dentists (85.9%) and male dentists (100%) generally complying, while dental assistants show lower adherence (72.6%).

Hand disinfection after removing gloves was performed by 32.5% of female dentists, 39.5% of male dentists, and only 7% of dental assistants. Wearing masks during dental work was reported at 100% among both female and male dentists, but only 84.9% among dental assistants. Goggles were higher among male dentists (100%) and lower among dental assistants (74.5%) and female dentists (77.6%).

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Changing clothes after visible contamination was reported at 100% for all groups, demonstrating excellent practice in maintaining cleanliness and preventing cross-contamination. Correct handling of sterile instruments was reported at 100% among both genders but only 81.3% among dental assistants.

Using rubber dams for an aseptic operation field was reported at 15.2% for female dentists and 30% for male dentists, with no data available for dental assistants. Recapping needles was performed by 11.6% of female dentists, none of the male dentists, and 12.5% of dental assistants.

Safe disposal of sharps was consistently high across all groups, with female dentists at 92.6%, male dentists at 100%, and dental assistants at 90.6%, indicating a strong understanding and adherence to proper sharps disposal protocols.

Table 3: Microbial Profile of Dental Clinics: Analysis of Colony-Forming Units for Common and Pathogenic Microorganisms

Group Parameter	Colony-Forming Units
Coagulase-negative staphylococci	284.5 ± 73.5
Micrococcus species	150.6 ± 34.85
Corynebacterium species	43.5 ± 10.85
Aerobic spore-formers	43.15.6 ± 29.65
Viridans streptococci	6.8 ± 4.6
Aspergillus species	5.7 ± 0.8
Non-fermenting bacteria Staphylococcus aureus	0.5 ± 0.3

The data on colony-forming units (CFUs) of various microorganisms isolated in dental clinics provides valuable insights into the microbial environment present in these settings. Understanding the prevalence and concentration of these microorganisms can help in identifying potential sources of contamination and informing infection control practices.

Coagulase-Negative Staphylococci

The most abundant microorganisms identified were coagulase-negative staphylococci, with a mean CFU count of 284.5 ± 73.5. Coagulase-negative staphylococci are generally considered opportunistic pathogens that can cause infections, particularly in immunocompromised individuals. Their high prevalence suggests they are a significant component of the microbial flora

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in dental clinics. Effective cleaning and disinfection protocols are necessary to manage these organisms and prevent potential infections.

Micrococcus Species

Micrococcus species were also present in notable quantities, with a mean CFU count of 150.6 ± 34.85. Micrococcus species are commonly found in the environment and can be part of the normal skin flora. Their presence in dental clinics highlights the importance of maintaining stringent hygiene practices to control environmental microbial contamination.

Corynebacterium Species

Corynebacterium species were detected with a mean CFU count of 43.5 ± 10.85. These bacteria are generally part of the skin flora and can be found in various environments. Their presence in dental settings underscores the need for effective surface disinfection and hand hygiene to minimize their potential impact on patient safety.

Aerobic Spore-Formers

Aerobic spore-formers were present at a mean CFU count of 43.15 ± 29.65. These microorganisms are known for their resilience and ability to form spores that can survive in harsh conditions. Their relatively high concentration suggests a need for rigorous cleaning procedures and possibly enhanced sterilization protocols to address their persistence in the clinic environment.

Viridans Streptococci

Viridans streptococci were found at a mean CFU count of 6.8 ± 4.6. These bacteria are part of the normal oral flora and are less prevalent compared to other microorganisms detected. While their lower concentration may indicate a lower risk of contamination from these species, their presence is still relevant for assessing the overall microbial load in dental settings.

Aspergillus Species

Aspergillus species were isolated with a mean CFU count of 5.7 ± 0.8. Aspergillus species are molds that can pose health risks, especially for individuals with compromised immune systems

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or respiratory conditions. Their presence, though lower in concentration, highlights the need for effective air filtration and control measures to prevent mold contamination.

Non-Fermenting Bacteria and Staphylococcus aureus

Non-fermenting bacteria, including Staphylococcus aureus, were detected with a mean CFU count of 0.5 ± 0.3. Although present in low numbers, Staphylococcus aureus is a significant pathogen known for its potential to cause infections. Its detection, even at low levels, indicates the importance of maintaining high standards of hygiene and sterilization to prevent any potential risk.

Discussion

The study found that the average concentration of PM2.5 in clinic treatment rooms was close to the WHO's recommended limit of 25 µg/m³, indicating dental procedures. The lower levels in waiting rooms suggest less impact from procedural activities or better ventilation. The study also found that the average concentration of CO2 in treatment rooms was 771 ± 54 ppm, below the ASHRAE standard's 1000 ppm limit. However, the higher levels in waiting rooms suggest potential ventilation issues, emphasizing the need for improved air quality management.

Our finding that the average concentration of PM2.5 in clinic treatment rooms was close to the WHO's recommended limit of 25 µg/m³ is significant. Dental procedures can indeed generate airborne particles, highlighting the need for effective air filtration systems in clinics. The use of N95 masks and environmental controls is emphasized by Chacko et al. to mitigate the inhalation of these particles. [10]

Our results showing the average concentration of CO2 in treatment rooms was 771 ± 54 ppm, which is below the ASHRAE standard's 1000 ppm limit, but higher levels in waiting rooms indicate potential ventilation issues. This points to the need for better air quality management in dental clinics, as suggested by Habashneh et al., who recommend air purifiers and enhanced ventilation systems, especially in the context of COVID-19. [11]

In addition to air quality, the environmental impact of dental practices has been a subject of study. Almutairi et al. emphasize the importance of choosing reusable and recyclable PPE to minimize CO2 emissions and resource usage. Ergonomic issues in dental clinics are also crucial;

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Borres et al. identify factors such as age, weekly working hours, workload, and posture that significantly affect discomfort scores among orthodontists. [9, 12]

The study reveals varied adherence to infection control protocols among dental professional groups, including female dentists, male dentists, and dental assistants. Hand hygiene practices were found to be more prevalent among dental assistants, with hand jewelry more common than among female dentists and male dentists. All groups reported 100% adherence to wearing gloves during dental work, but there was a notable difference in adherence to glove removal. Hand disinfection after removing gloves was performed by 32.5% of female dentists, 39.5% of male dentists, and only 7% of dental assistants. Handwashing sterile instruments was 100% among both genders, but only 81.3% among dental assistants. Safe disposal of sharps was consistently high across all groups.

Our observation that hand hygiene practices are more prevalent among dental assistants, with hand jewelry being more common, finds some support in other studies. For instance, Menawi et al. found high compliance with the use of personal protective equipment (PPE), including gloves, among dental professionals in the Nablus and Tulkarm districts, but noted lower compliance with instrument sterilization measures. Similarly, Amnuaiphanit et al. reported that 86.7% of Thai dental professionals modified their practices during the COVID-19 pandemic, which included enhancing local source control of dental aerosols and improving sterilization procedures. [13, 14]

Our finding that adherence to glove removal and hand disinfection after removing gloves varies among professional groups (with only 7% of dental assistants disinfecting their hands) is concerning. This is somewhat corroborated by Natto et al., who observed high usage of gloves and masks during procedures in dental clinics in Jeddah, Saudi Arabia, but less consistent adherence to using sterile gloves and disposable gowns for surgeries. [15]

The complete adherence to handwashing sterile instruments by dentists of both genders, contrasted with 81.3% among dental assistants, underscores a gap in infection control practices. Al-Makramani emphasizes the importance of proper sterilization and disinfection of items used in prosthodontic work to minimize the risk of disease transmission. Moreover, the consistent high

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adherence to the safe disposal of sharps across all groups aligns with the findings of Ali et al., who stressed the necessity of PPE and proper disposal methods to prevent the transmission of infections, particularly COVID-19. [16]

The varied adherence to infection control protocols among dental professionals highlights the need for targeted training and consistent enforcement of guidelines. Makramani. found that knowledge acquisition through training significantly impacts occupational infection control behavior among dental professionals. This suggests that improving training and information dissemination could enhance adherence to infection control practices across all groups. [17]

The data on colony-forming units (CFUs) of various microorganisms in dental clinics provides valuable insights into the microbial environment. Coagulase-negative staphylococci are the most abundant microorganisms, causing infections in immunocompromised individuals. Micrococcus species are also present, highlighting the importance of stringent hygiene practices. Corynebacterium species are part of the skin flora and require effective surface disinfection and hand hygiene. Aerobic spore-formers are known for their resilience and need rigorous cleaning procedures. Viridans streptococci are part of the normal oral flora and less prevalent, but their presence is still relevant for assessing the overall microbial load. Aspergillus species pose health risks, and non-fermenting bacteria, including Staphylococcus aureus, are detected, highlighting the need for effective air filtration and control measures.

Our finding that coagulase-negative staphylococci are the most abundant microorganisms in dental clinics is consistent with other studies. These bacteria are known to cause infections in immunocompromised individuals, emphasizing the importance of proper hand hygiene and surface disinfection. Akbar et al. also stress the need for routine disinfection protocols to control biofilm growth and reduce microbial contamination, including species like Staphylococcus. [18]

The presence of Micrococcus species further underscores the necessity for stringent hygiene practices in dental clinics. These bacteria are part of the normal skin flora and can contaminate surfaces and instruments if not properly disinfected. The study by Singh et al. found that earrings worn by female dentists were 100% contaminated with bacteria, highlighting potential sources of cross-contamination in dental settings. [19]

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Corynebacterium species, being part of the skin flora, require effective surface disinfection and hand hygiene to prevent their spread. Akbar et al. also noted the presence of Corynebacterium in dental unit waterlines, pointing to the need for comprehensive disinfection protocols. [18]

The resilience of aerobic spore-formers necessitates rigorous cleaning procedures in dental clinics. The study by Totaro et al. demonstrated the effectiveness of a water disinfection method based on osmosis and chlorine dioxide in significantly reducing microbial contamination in dental clinics. [20]

Viridans streptococci, part of the normal oral flora, are less prevalent but still relevant for assessing the overall microbial load. Their presence indicates the need for continuous monitoring and effective disinfection practices. The use of preprocedural mouth rinses, as highlighted by Nagraj et al., can help reduce the microbial load in aerosols generated during dental procedures. [21]

The detection of Aspergillus species poses health risks, particularly to immunocompromised patients. The study by Omran et al. identified risk factors for fungal contamination of dental unit waterlines, including dental specialty and the age of the dental unit. This underscores the importance of regular maintenance and disinfection of dental equipment. [22]

The presence of non-fermenting bacteria, including Staphylococcus aureus, highlights the need for effective air filtration and control measures. Chen et al. emphasize the importance of controlling biofilm contamination in dental unit waterlines to prevent the growth of potential human pathogens. [23]

Conclusions:

The study on environmental health and safety in dental clinics has provided a comprehensive overview of critical parameters affecting the safety and quality of dental practice. The analysis of air quality, infection control compliance, and microbial contamination has revealed key findings that underscore the importance of maintaining high standards in dental environments.

Air Quality: The elevated levels of particulate matter (PM2.5) in treatment rooms compared to waiting areas highlight the impact of dental procedures on air quality. Although CO2

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levels in both treatment and waiting rooms are within acceptable limits, the variation in CO2 concentrations points to potential issues with ventilation, particularly in waiting areas.

Infection Control Compliance: The study identified significant variations in infection control practices among different dental professionals. While adherence to certain protocols, such as wearing gloves and changing clothes after contamination, is high, other areas, such as hand hygiene and the use of rubber dams, show room for improvement. This variability suggests the need for enhanced training and policy reinforcement.

Microbial Contamination: The presence of a diverse range of microorganisms, including coagulase-negative staphylococci and Micrococcus species, emphasizes the importance of effective cleaning and disinfection. The detection of potentially pathogenic microorganisms like Staphylococcus aureus, even in low quantities, highlights the need for rigorous infection control measures to prevent contamination and ensure patient safety.

Recommendations:

Based on the study's findings, the following recommendations are proposed to enhance environmental health and safety in dental clinics:

1. **Improve Air Quality Management**:
    - **Enhance Ventilation**: Invest in advanced ventilation systems to ensure that CO2 levels remain within safe limits, particularly in waiting areas. Regularly maintain and calibrate air quality monitors to ensure accurate readings.
    - **Increase Filtration**: Implement high-efficiency particulate air (HEPA) filters in treatment rooms to reduce PM2.5 levels and improve overall air quality.
2. **Strengthen Infection Control Practices**:
    - **Reinforce Hand Hygiene**: Conduct regular training sessions on hand hygiene for all dental staff, emphasizing the importance of proper hand washing and disinfection before and after dental procedures.

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- **Standardize Protocols**: Develop and enforce standardized protocols for glove use, including removal between different activities and disinfection after glove removal. Ensure consistent adherence to these protocols through regular audits.
- **Promote Use of Rubber Dams**: Encourage the use of rubber dams during invasive procedures to maintain an aseptic field and reduce microbial contamination.
- **Address Jewelry Use**: Implement policies restricting the wearing of hand jewelry during clinical activities to minimize potential sources of contamination.

3. **Enhance Microbial Control**:
    - **Improve Cleaning Procedures**: Review and upgrade cleaning and disinfection protocols to address the presence of resilient microorganisms such as aerobic spore-formers. Ensure that all surfaces and equipment are effectively cleaned and sterilized.
    - **Monitor Microbial Load**: Regularly monitor microbial levels in dental clinics and adjust cleaning practices as needed to manage and reduce microbial contamination.
4. **Foster a Culture of Safety**:
    - **Continuous Training**: Provide ongoing training and education for dental professionals on the latest infection control practices and environmental health standards.
    - **Regular Audits**: Conduct regular audits and inspections to ensure compliance with infection control and environmental health protocols. Use audit findings to implement corrective actions and improve practices.

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