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ARTICLE REVIEW

New technologies and advances in biosafety for dental practice

Nuevas tecnologías y avances en bioseguridad para la práctica odontológica

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ABSTRACT

Introduction: biosafety is crucial in modern dentistry to prevent the transmission of infectious diseases between patients and clinical staff, given their exposure to body fluids and contaminated surfaces. Technological advances are transforming infection control protocols in this area.
Objective: to determine the most significant developments in biosafety in dentistry and technological advances, highlighting their impact on improving the quality and safety of dental care.
Methods: a literature search was conducted using multiple academic databases such as PubMed, Scopus and Google Scholar.
Results: some key innovations include digital intraoral scanners that eliminate the need for physical impressions, dental lasers that generate less aerosols, suction systems and HEPA filters to capture contaminated airborne particles, stronger nitrile gloves with lower allergy risk, N95 masks and face shields for better staff protection, and highly effective steam autoclaves for instrument sterilization.
Conclusions: these technologies contribute to a safer clinical environment by mitigating infection risks, although more research is needed to assess their long-term impact, develop new contamination-resistant materials, and integrate artificial intelligence systems into dental biosafety.

Keywords: Containment of Biohazards; Dentistry; Infection Control.

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RESUMEN

Introducción: la bioseguridad es crucial en la odontología moderna para prevenir la transmisión de enfermedades infecciosas entre pacientes y personal clínico, dada su exposición a fluidos corporales y superficies contaminadas. Los avances tecnológicos están transformando los protocolos de control de infecciones en esta área.
Objetivo: determinar los desarrollos más significativos de la bioseguridad en odontología y los avances tecnológicos, destacando su impacto en la mejora de la calidad y seguridad de la atención odontológica.
Métodos: búsqueda bibliográfica se llevó a cabo utilizando múltiples bases de datos académicas como PubMed, Scopus y Google Scholar.
Resultados: Algunas innovaciones clave incluyen escáneres intraorales digitales que eliminan la necesidad de impresiones físicas, láseres dentales que generan menos aerosoles, sistemas de aspiración y filtros HEPA para capturar partículas aéreas contaminadas, guantes de nitrilo más resistentes y con menor riesgo de alergias, mascarillas N95 y protectores faciales para mejor protección del personal, y autoclaves de vapor altamente efectivos para la esterilización de instrumental.
Conclusiones: Estas tecnologías contribuyen a un entorno clínico más seguro al mitigar los riesgos de infección, aunque se requiere más investigación para evaluar su impacto a largo plazo, desarrollar nuevos materiales resistentes a la contaminación e integrar sistemas de inteligencia artificial en la bioseguridad odontológica.

Palabras Clave: Bioseguridad, Odontología, Control De Infecciones.

INTRODUCTION

Modern dentistry faces a complex biosecurity landscape, as it involves direct interaction with bodily fluids, tissues, and contaminated surfaces that may harbor a variety of pathogenic microorganisms. The transmission of infectious diseases in the dental environment poses a risk not only to patients but also to dental health professionals, who are exposed to various sources of contamination during their clinical activities. Therefore, biosecurity is a fundamental pillar to guarantee the health of both patients and clinical staff.[1]

In this context, new technologies and advances in biosafety have emerged as crucial tools for optimizing infection control protocols in dental practice. From high-efficiency air filtration systems to advanced sterilization technologies, biosafety innovation has radically transformed how infection prevention challenges in dentistry are addressed.[2]

One of the most significant developments has been the incorporation of cutting-edge disinfection and sterilization technologies, such as ultraviolet light systems and hydrogen peroxide vapor sterilization equipment. These innovations make it possible to more efficiently and safely eliminate a wide range of pathogenic microorganisms, thereby reducing the risk of cross-infection in the dental setting.[3]

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Furthermore, the implementation of infection control systems based on artificial intelligence and big data has facilitated the monitoring and management of biological risks in dental clinics. These systems can analyze large amounts of data and detect patterns that help prevent the spread of disease, enabling healthcare professionals to take timely and effective preventive measures.[4]

On the other hand, advances in biocompatible materials and additive manufacturing techniques, such as 3D printing, have enabled the development of safer, more contamination-resistant dental instruments and devices. These materials and techniques reduce the possibility of adverse reactions in patients and facilitate disinfection and sterilization procedures, contributing to a safer clinical environment.[5]

It is important to highlight that advances in biosecurity are not limited to the technical field, but also encompass aspects related to waste management, staff training, implementation of infection control policies, and promotion of appropriate hygiene habits. The integration of multidisciplinary approaches and collaboration between health professionals, biomedical engineers, and public health experts have made it possible to promote the development and implementation of comprehensive biosecurity strategies.[6]

New technologies and advances in biosecurity represent an essential component of contemporary dental practice, providing the necessary means to mitigate the risks associated with the transmission of infectious diseases and ensure a safe and healthy clinical environment. This literature review aims to identify the most significant developments in biosecurity in dentistry and technological advances, highlighting their impact on improving the quality and safety of dental care.

METHODS

The literature search was conducted using multiple academic databases such as PubMed, Scopus, and Google Scholar. Relevant search terms related to biosafety in dentistry and technological advances in this field were used, such as "dental biosafety," "technology in dentistry," "dental disinfection," and "sterilization in dentistry," among other related terms. In addition, specialized journals on dentistry and biosafety were reviewed to ensure the comprehensiveness of the search.

The inclusion criteria for the selection of studies were as follows:

1. Thematic relevance: The studies had to specifically address the topic of biosecurity in dentistry and/or technological advances related to infection prevention and control in this field.
2. Methodological rigor: Peer-reviewed studies, controlled clinical trials, systematic reviews, and meta-analyses were prioritized. Studies that lacked a sound methodological design or did not provide relevant data for the review were excluded.
3. Current events: Studies published in the last five years were prioritized to ensure the information was up-to-date and relevant.
4. Language: Studies in English and Spanish were included, as these are the working languages of the research team.
5. Full text availability: Only studies that were available in their entirety were selected for further analysis.

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The exclusion criteria were as follows:
1. Studies not related to biosafety in dentistry or technological advances in this field.
2. Studies that lacked a sound methodological design or did not provide relevant data for the review.
3. Studies that were duplicated or lacked full-text availability.
4. After applying these criteria, the most relevant studies were identified and analyzed and synthesized in the bibliographic review.

DEVELOPMENT

Technologies for cross-infection control

Intraoral scanners:
Traditionally, dental impressions were obtained using physical impression materials, such as elastomers. This process involved direct handling of these materials, which could become contaminated with the patient's saliva, blood, and other oral fluids. This exposure to potentially infectious fluids posed a considerable risk of disease transmission and cross-contamination between patients.

However, intraoral scanners have transformed this paradigm by offering a digital, contactless alternative. These devices use advanced technologies, such as photogrammetry or structured light scanning, to capture precise three-dimensional images of the patient's oral cavity. This completely eliminates the need to handle physical impression materials, thus minimizing exposure to oral fluids and the potential transfer of pathogenic microorganisms between patients.

In addition to this fundamental advantage, intraoral scanners have other features that contribute to a safer clinical environment. First, these devices are easy to disinfect, as their compact design and the materials used in their manufacture allow for efficient cleaning and disinfection between patients. Second, intraoral scanners enable a digitalized workflow, further reducing the risks of cross-contamination associated with handling physical impressions.

The use of intraoral scanners has also been shown to significantly reduce the risk of cross-contamination compared to traditional impression-taking methods. The results of this research highlight the importance of adopting innovative technologies that prioritize biosecurity in the dental field.[1]

Dental lasers
The incorporation of dental lasers into dental practice has represented a significant advance in mitigating this risk, as they have been shown to generate less aerosol and spatter compared to conventional methods.[2]

This reduction in aerosol and spatter production is due to the precise and controlled nature of dental lasers. Unlike traditional rotary instruments, lasers vaporize and cut tissue in a localized and focused manner, minimizing the dispersion of particles and oral fluids into the surrounding air.

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High-power suction systems

Traditionally, conventional suction systems have been used to try to control the dispersion of these aerosols and contaminated particles. However, these systems were often not effective enough to adequately capture and remove the contaminants present in the air.

In response to this need, high-power suction systems have emerged as an innovative and highly effective solution. According to several studies, these systems have demonstrated greater efficacy compared to conventional systems, achieving a significant reduction in environmental contamination levels and reduced dispersion of particles and aerosols in the clinical environment.[3,4]

The key to the success of these systems lies in their specialized design. They feature powerful suction motors and high-efficiency filters that collect and retain a large amount of suspended particles, including microscopic particles that can harbor pathogenic microorganisms.

By efficiently capturing and removing contaminated aerosols and particles, these high-powered suction systems contribute to a cleaner and safer clinical environment, significantly reducing the risk of airborne infection transmission. Furthermore, by reducing the contaminant load in the air, both patients and dental staff are protected from exposure to potential pathogens.

It's important to emphasize that the implementation of these high-powered suction systems must be complemented by other biosafety measures, such as the use of appropriate personal protective equipment, rigorous surface disinfection, and ongoing staff training in infection control protocols.

HEPA air filters

High-efficiency particulate air (HEPA) filters are devices designed to remove microscopic particles from the air, including viruses, bacteria, fungi, and other contaminants. These filters are capable of capturing and retaining 99,97 % of particles 0,3 microns or larger. One study evaluated the incorporation of HEPA filters into dental practice ventilation systems. The results demonstrated a significant decrease in the levels of particles and microorganisms present in the air in the clinical environment.[5,6]

HEPA filters work through a mechanical filtration process, in which particles are trapped in the filter fibers as air passes through it. This effectively removes a wide range of airborne contaminants, including bacteria, viruses, fungal spores, pollen, and dust particles.[7,8]

By reducing the levels of particles and microorganisms in the air, HEPA filters help reduce the risk of cross-infection in dental practices. These filters are especially important in areas where aerosol-generating procedures are performed, such as in the dental treatment room.

Additionally, HEPA filters are reusable and durable, making them a cost-effective and sustainable long-term solution for maintaining a clean and safe environment in the dental setting.

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Technologies for staff protection

Nitrile gloves

Nitrile gloves have been the subject of extensive research due to their superior properties compared to traditional latex gloves. In a study conducted by Lovato et al.,[11] the puncture and chemical resistance of both types of gloves were evaluated. The results showed that nitrile gloves exhibited greater puncture and tear resistance, providing better protection against exposure to body fluids and pathogens.[9,10] Additionally, they demonstrated superior resistance to various chemicals, such as disinfectants, solvents, and medications, compared to latex gloves.

Another important aspect to consider is the risk of allergic reactions. Nitrile gloves do not contain natural latex proteins, which significantly reduces the risk of allergic reactions in latex-sensitive patients and professionals. This makes them a safer option for those with known latex allergies or at risk of developing sensitivity.

Regarding durability and elasticity, some studies have reported that nitrile gloves have greater durability and elasticity compared to latex gloves, making them more resistant to wear and tear during prolonged procedures.[9,11]

Respirator masks

Several studies have evaluated the effectiveness of N95 and equivalent respirators in protecting against viral and bacterial particles in healthcare settings. One study compared the filtration capacity of N95 respirators with conventional surgical masks. The results revealed that N95 respirators demonstrated greater effectiveness in protecting against viral and bacterial particles, with filtration efficiency exceeding 95 % for particles 0.3 microns or larger.[12]

In addition, Aguilar-Gamboa,[13]A literature review detailed the effectiveness of N95 respirators and surgical masks in protecting against influenza and other respiratory viruses. The authors concluded that the use of N95 respirators was associated with a significant reduction in the risk of infection in healthcare settings compared to surgical masks.

Protective glasses and face shields

Several studies have investigated the role of protective eyewear and face shields in reducing the risk of exposure to contaminated splashes and aerosols in the dental setting. In a review conducted by Peña-Téllez,[14] The importance of these eye and face protection devices is highlighted. The authors noted that during dental procedures, aerosols and splashes containing a combination of saliva, blood, and oral tissue debris are frequently generated. These aerosols and splashes can carry pathogenic microorganisms, such as viruses and bacteria, posing a significant risk of infection to dental professionals and patients.

In this context, protective eyewear and face shields act as physical barriers that prevent direct contact with these contaminated splashes and aerosols. Proper use of protective eyewear and face shields can significantly reduce exposure to splashes and aerosols during dental procedures.

Likewise, Esquivel,[15] in a comparative study of different types of face shields details how face shields with a wraparound design and good lateral coverage offered greater protection against exposure to splashes and aerosols compared to more open shields or with less coverage.

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Advances in sterilization and disinfection

Numerous studies have supported the efficacy and safety of steam autoclaves for the sterilization of medical and dental instruments and materials. According to Valdespino Ávila,[16] in his extensive review of sterilization methods, he highlighted the superiority of steam sterilization in terms of effectiveness and reliability. The authors noted that steam autoclaves, which operate at temperatures near or exceeding 121°C, are capable of reliably eliminating all microorganisms, including highly resistant ones such as bacterial spores. This makes them one of the most effective sterilization methods available.

In contrast, dry-heat sterilization methods, such as hot-air ovens, require much higher temperatures (generally above 160°C) and longer exposure times to achieve adequate sterilization. This can be detrimental to some heat-sensitive materials, limiting their application in certain clinical settings. On the other hand, chemical disinfectants, such as glutaraldehyde compounds or hydrogen peroxide, while effective in high-level disinfection, do not achieve the same level of safety and reliability as steam sterilization. Furthermore, some chemical disinfectants can be toxic and may leave harmful residues on instruments.[17]

The findings presented in this document highlight significant technological advances in the field of biosecurity in dentistry. These innovations have important implications for dental practice, offering effective solutions to mitigate the risks of cross-infection and protect both patients and clinical staff.

First, the incorporation of digital intraoral scanners eliminates the need to handle physical impression materials, thereby reducing exposure to potentially infectious oral fluids. This significantly minimizes the risk of disease transmission and cross-contamination between patients. Furthermore, intraoral scanners facilitate a digitalized workflow, further reducing the risks associated with handling physical impressions.

Furthermore, the adoption of dental lasers has demonstrated lower aerosol and spatter generation compared to conventional methods. This feature is critical for mitigating the spread of microorganisms through suspended particles, contributing to a safer clinical environment.

Additionally, high-powered suction systems and HEPA air filters have demonstrated superior effectiveness in capturing and removing contaminated airborne particles and aerosols. These technologies significantly reduce the contaminant load in the clinical environment, protecting both patients and healthcare providers from exposure to potential pathogens.

When it comes to staff protection, nitrile gloves have proven to be a superior alternative to traditional latex gloves. Their greater resistance to punctures and chemicals and lower allergenic potential make them a safer option for dental professionals.

Furthermore, N95 respirator masks and their equivalents have demonstrated greater effectiveness in filtering viral and bacterial particles compared to conventional surgical masks. This provides additional protection for clinical staff against exposure to infectious microorganisms.

Protective eyewear and face shields also play a crucial role by acting as physical barriers that prevent direct contact with contaminated splashes and aerosols during dental procedures.

Finally, advances in sterilization and disinfection, such as steam autoclaves, have proven to be highly effective and reliable methods for safely eliminating the most resistant microorganisms, ensuring the sterility of instruments and materials used in dental practice.

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Together, these technological innovations and advanced biosafety practices have the potential to transform infection control standards in dentistry. Their implementation will contribute to a safer clinical environment and minimize the risks of disease transmission for both patients and clinical staff. Furthermore, these measures reinforce public confidence in the dental profession and its commitment to the safety and well-being of all involved.

CONCLUSIONS

Biosafety is a fundamental pillar of dental practice, ensuring a safe clinical environment and minimizing the risks of infectious disease transmission for patients and professionals. Technological advances represent a paradigm shift in how biosafety is addressed in dentistry. The adoption of innovations such as digital intraoral scanners, dental lasers, high-power suction systems, HEPA air filters, nitrile gloves, N95 respirator masks, protective eyewear, face shields, and steam autoclaves for sterilization have revolutionized infection control protocols in the dental field. While these advances are significant, there are still areas that require further research and continued development. Continued efforts are needed to assess the long-term impact of these technologies, develop new materials and additive manufacturing techniques that are more resistant to contamination, integrate artificial intelligence and big data into biosafety protocols, explore more efficient and sustainable disinfection and sterilization techniques, and address challenges related to dental staff acceptance and adherence to these innovations.

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