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A Review of Global Perspectives on Oral Health: Challenges, Accessibility, and Emerging Technologies

Hadi Assadian[1]

1. Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

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[*]**Corresponding Author**
Hadi Assadian, Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Email: hd.asdn@scident.ir

Abstract

Background and objectives: To provide a comprehensive review of the multifaceted challenges, disparities, and emerging solutions in global oral health, emphasizing the critical role of innovative technologies and public health initiatives.

Materials and methods: Oral health is a critical yet often overlooked component of global health, significantly impacting systemic health and quality of life. This review examines the challenges and disparities in oral health across various regions, highlighting the global burden of oral diseases and the socioeconomic and geographic factors hindering access to dental care.

Results: The review reveals significant socioeconomic and geographic disparities in access to dental care, underscoring the importance of preventive measures and public health initiatives. Innovative solutions and emerging technologies are shown to be transforming dental care, improving outcomes and accessibility. The impact of COVID-19 on oral health services highlights the resilience and adaptability of health systems in response to unprecedented challenges.

Conclusion: The need for integrated and equitable approaches to address the global oral health crisis is emphasized, advocating for sustained investment in innovative technologies and comprehensive public health strategies. The review underscores the critical connection between oral and systemic health, particularly in low- and middle-income countries, and highlights the essential role of public health initiatives, innovative technologies, and resilient systems in achieving equitable dental care and overall health improvement.

Keywords: Dental care; Global health; Oral health; Public health; Preventive health care.

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1. Introduction

Oral health is an integral component of overall health and well-being, yet it remains a neglected area in many parts of the world. Dental diseases, such as dental caries, periodontal diseases, and oral cancers, are among the most prevalent health issues globally, affecting individuals of all ages and socioeconomic backgrounds (1,2). The burden of these diseases is not evenly distributed, with low- and middle-income countries (LMICs) bearing a disproportionately high share (3). In addition, oral health is closely linked to systemic health, influencing conditions such as cardiovascular disease, diabetes, and respiratory infections (4). Despite the significant impact of oral health on general health, access to dental care is often limited by socioeconomic, geographic, and systemic barriers (5). In many regions, particularly in LMICs, inadequate infrastructure, a shortage of dental professionals, and financial constraints hinder the delivery of essential dental services (6). Consequently, there is a pressing need for comprehensive public health strategies and innovative solutions to address these challenges and improve oral health outcomes globally.

This review explores the global health challenges in dentistry, providing an overview of the current landscape and emphasizing the importance of oral health to systemic health. It delves into the global burden of oral diseases, examining the disparities in access to dental care and the role of

prevention and public health initiatives. Additionally, it highlights global health policies and initiatives aimed at reducing the burden of dental diseases, as well as the innovative solutions and technologies that are transforming the field of dentistry. The review also discusses the profound impact of the COVID-19 pandemic on global oral health and concludes with future directions and solutions to enhance oral health on a global scale. By addressing these topics, the review aims to underscore the critical importance of oral health within the broader context of global health and to inspire concerted efforts to tackle the challenges that lie ahead.

2. Search strategy

To conduct this scoping review, a comprehensive and systematic search of the available literature published between 1990 and 2024 was meticulously carried out. The search process utilized various academic databases to ensure extensive coverage of relevant studies from diverse disciplines. The initial search yielded a total of 336 studies, comprising both original research articles and review papers. These studies encompassed a wide array of topics related to the objectives of the review, reflecting advancements in the field over multiple decades.

Following the identification of these studies, a rigorous selection process was employed to determine their suitability for inclusion in the final review. This process involved an initial screening based on titles and abstracts to eliminate irrelevant or duplicated entries. Subsequently, the full texts of potentially eligible studies were thoroughly examined to assess their alignment with the review's criteria, such as relevance to the topic, methodological quality, and contribution to the understanding of key concepts. Studies were evaluated for their scientific rigor, including the appropriateness of the research design, sample size, data analysis methods, and ethical considerations.

Out of the 336 initially identified studies, 19 were ultimately selected for inclusion in this scoping review. The selected studies were chosen to represent a balanced and comprehensive perspective on the subject matter, ensuring that both historical context and contemporary insights were captured. This methodical approach aimed to provide an evidence-based foundation for the review, with the selected studies serving as the cornerstone for analyzing and synthesizing the existing knowledge in the field. on Mueller Hinton agar and incubated at 37°C for 24 hours. The plate with the lowest concentration of extract that showed no bacterial growth indicated the MBC of the extract (13-15).

3. Results

3.1. Overview of the Global Health Landscape in Dentistry

Global health refers to the health of populations in a worldwide context and transcends the perspectives and concerns of individual nations (7). In the context of dentistry, global health encompasses the promotion, prevention, and treatment of oral diseases and conditions, and emphasizes the need for international collaboration to address disparities in oral health care access, quality, and outcomes (2). It involves understanding and addressing the social, economic, and environmental determinants that influence oral health on a global scale (8). Global health in dentistry is not merely about providing dental care across different countries; it involves a holistic approach to understanding how dental health interacts with a myriad of factors that affect populations worldwide. This includes:

3.1.1. Epidemiological Studies

Monitoring the prevalence and incidence of dental diseases such as caries, periodontal diseases, and oral cancers globally.

3.1.2. Health Systems Strengthening

Enhancing the capacity of health systems to deliver effective, safe, and high-quality dental care.

3.1.3. Policy Development

Crafting policies that promote equitable access to dental care and the integration of oral health into broader health strategies.

3.2. The Importance of Oral Health to Systemic Health

Oral health plays a vital role in maintaining overall health and quality of life. Poor oral health can lead to significant pain, discomfort, and social and functional impairments (9). Bacteria from periodontal infections can enter the bloodstream, causing inflammation and contributing to the development of systemic conditions. Hence, maintaining good oral health is essential not only for preventing dental issues but also for safeguarding overall health. Moreover, there is a well-documented relationship between oral health and systemic health (10). For instance, periodontal disease has been linked to cardiovascular diseases and research has demonstrated that periodontal pathogens can contribute to atherosclerosis, leading to heart disease and stroke. Studies have found that individuals with periodontitis are at a higher risk of developing cardiovascular conditions (11). In addition, there is a bidirectional relationship between diabetes and periodontal disease. Diabetes increases the risk of periodontal disease, and severe periodontal disease can exacerbate blood glucose levels, complicating diabetes management (12). Additionally, poor oral hygiene and periodontal disease have been linked to respiratory infections such as pneumonia, especially in vulnerable populations like the elderly (4). Also, periodontal disease in pregnant women has been associated with preterm birth, low birth weight, and preeclampsia (13).

Despite the recognized importance of oral health, significant global challenges remain in achieving optimal oral health for all. These challenges include difficulties in access to dental care, especially in rural and low-income areas, economic disparities, due mainly to the high cost of dental treatments, lack of emphasis on preventive measures and education, and inaccessibility of technological advancements in dentistry.

3.3. WHO's 2021 Resolution on Oral Health

The World Health Organization (WHO) has been actively woking to integrate oral health into global health policies, recognizing the significant impact of oral diseases on overall health and well-being (14). In 2021, the WHO's World Health Assembly approved a historic resolution on oral health, which set forth several key objectives and recommendations as follows:

3.3.1. Addressing Risk Factors

The resolution calls on member states to tackle major risk factors for oral diseases, including excessive consumption of free sugars, tobacco use, and the harmful use of alcohol. These risk factors are shared with other noncommunicable diseases (NCDs), highlighting the interconnectedness of oral health with broader health issues.

3.3.2. Preventive Approach

The resolution advocates moving away from the traditional focus on treatment toward a preventive strategy. This involves encouraging oral health practices in families, schools, and workplaces, and providing timely, comprehensive, and inclusive care through the primary health care system.

3.3.3. Universal Health Coverage

The resolution emphasizes the importance of including oral health-care interventions in universal health coverage (UHC) programs. This means that oral health should be an integral part of national health coverage packages, making dental care more accessible and affordable for all populations.

3.3.4. Global Strategy and Action Plan

The WHO was tasked with developing a draft global strategy on tackling oral diseases by 2022, which would be considered by WHO governing bodies in 2023. This strategy would then be translated into an action plan for oral health.

3.3.5. Best Buy Interventions

The resolution calls for the development of “best buy” interventions on oral health, which are cost-effective measures that can significantly improve oral health outcomes.

3.3.6. Inclusion of Noma

The resolution also explores the inclusion of noma, a severe gangrenous disease affecting children, within the roadmap for neglected tropical diseases.

3.3.7. Reporting and Monitoring

WHO is required to report back on progress and results until 2031 as part of the consolidated report on noncommunicable diseases. This ensures that the implementation of the resolution is monitored and evaluated over time.

The 2021 resolution on oral health is a landmark step towards recognizing the importance of oral health in the global health agenda. By integrating oral health into Universal Health Coverage (UHC) programs and focusing on preventive measures, the resolution aims to reduce the burden of oral diseases and improve overall health outcomes. It also highlights the need for international collaboration and policy development to address disparities in oral health care access and quality.

3.4. Global Burden of Oral Diseases

Oral health diseases are among the most widespread noncommunicable diseases globally, affecting nearly 45% of the world's population, which equates to approximately 3.5 billion people (15). These diseases span all age groups, from early childhood to old age, and have significant implications for overall health and well-being. Dental caries is the most common oral health condition, impacting an estimated 2 billion people worldwide. Untreated dental caries can lead to pain, infection, and tooth loss (16). Periodontal disease affects around 1 billion people globally and is a major cause of tooth loss (17). Each year, around 380,000 new cases of oral cancer are identified, with common risk factors including tobacco use, alcohol intake, and infection with human papillomavirus (HPV) (18). Untreated dental caries and periodontal disease can lead to significant functional and aesthetic issues. Orofacial clefts, among the most common congenital conditions, affect the structure of the mouth and face, requiring specialized care and treatment (19). Noma, a severe gangrenous disease primarily affecting children in low-resource settings, starts in the mouth and spreads to other parts of the face (20). The burden of oral diseases is disproportionately higher in low- and middle-income countries (LMICs), where three out of every four affected people reside. These regions often face barriers to accessing preventive and curative dental care, leading to higher rates of untreated conditions. Vulnerable and disadvantaged populations, including those on low incomes, people living with disabilities, older adults, and those in remote and rural areas, carry a higher burden of oral diseases (21). Common risk factors for oral diseases include high sugar intake, tobacco use, use of alcohol, and poor oral hygiene (22). These factors are shared with other noncommunicable diseases (NCDs) such as cardiovascular diseases, diabetes, and respiratory infections, highlighting the interconnectedness of oral health with broader health issues. Preventive measures, such as reducing sugar consumption, promoting tobacco cessation, and improving oral hygiene practices, are crucial for reducing the incidence of oral diseases. Access to affordable and comprehensive dental care is essential for the early detection and treatment of oral health conditions. Public health campaigns, water fluoridation programs, and community-based preventive services play a vital role in improving oral health outcomes.

The economic burden of untreated oral health diseases is substantial, impacting both individuals and society at large. Untreated oral health conditions, such as dental caries and periodontal diseases, can lead to increased healthcare costs and significant productivity losses. For instance, a study by Qian et al. (23) found that oral pain and untreated dental caries were associated with oral health-related productivity loss in the USA. The study revealed that individuals with untreated dental caries were 2.18 times more likely to experience productivity loss compared to those without caries. Moreover, the World Health Organization (WHO) reported that oral

diseases cost the world $710 billion annually in direct treatment costs and productivity losses. This includes $323 billion in productivity losses due to oral diseases (15). In a cross-sectional study of Japanese workers, Shimada et al. (24) found that poor oral health was associated with various work problems, including stress, lack of focus, and lack of energy. Workers with poor self-reported oral health were 3.58 times more likely to report work problems compared to those with excellent oral health.

3.5. Access to Dental Care

Challenges in low- and middle-income countries (LMICs) include several key issues related to the availability, affordability, and quality of dental care services. Many regions face a severe shortage of dental professionals and facilities, particularly in rural and low-income areas, making it difficult for individuals to receive necessary care. Infrastructure gaps, such as the lack of dental clinics and equipment, further limit the availability of dental care services, especially in remote and underserved areas. The high cost of dental treatments often puts them out of reach for low-income populations, leading to untreated conditions and exacerbating health inequalities. Additionally, the lack of insurance coverage for dental care, which is often a privately financed service, contributes to affordability issues (25). Significant variation exists in the quality of dental care services across different regions, with some areas experiencing substandard care due to a lack of trained professionals and inadequate facilities. There is also a lack of emphasis on preventive measures and education, which are crucial for reducing the incidence of oral diseases. Public health campaigns and community-based preventive services are essential for improving oral health outcomes(26).

There is also a lack of emphasis on preventive measures and education, which are crucial for reducing the incidence of oral diseases. Public health campaigns and community-based preventive services are essential for improving oral health outcomes (3). As the global population ages, the prevalence of chronic conditions, including oral diseases, increases, requiring specialized geriatric dental care. Integrating new technologies into dental practice is essential for improving diagnostics, treatment, and patient outcomes, but it also poses challenges in terms of affordability and accessibility (26). Vulnerable and disadvantaged populations, including those on low incomes, people living with disabilities, older adults, and those in remote and rural areas, carry a higher burden of oral diseases and often face barriers to accessing preventive and curative dental care, leading to higher rates of untreated conditions and poorer health outcomes. Oral diseases are among the most widespread noncommunicable diseases globally, affecting nearly 45% of the world's population, with the burden disproportionately higher in LMICs, where three out of every four affected people reside. Southeast Asia and Sub-Saharan Africa experience the highest burden of untreated dental caries, while oral cancer rates in South Asia are high due to the use of smokeless tobacco products. Addressing these challenges requires a multifaceted approach, this involves improving integration with primary healthcare, building workforce capacity, focusing on preventive measures, and promoting policy reforms. Partnering with NGOs, international bodies, and the dental industry is essential for advancing dental care in these settings (27).

Financial constraints are a primary barrier, as the high cost of dental treatments often puts them out of reach for low-income individuals and families, leading to untreated conditions and exacerbating health inequalities. Additionally, the shortage of dental professionals, particularly in low- and middle-income countries and rural areas, limits the availability of necessary care. This shortage is compounded by a lack of infrastructure, including inadequate numbers of dental clinics and insufficient equipment, which further restricts access to quality dental services (6). These barriers create significant challenges for vulnerable and disadvantaged populations, making it difficult for them to receive the preventive and curative care needed to maintain oral health and overall well-being. Addressing these barriers requires comprehensive strategies, including policy changes, increased investment in dental healthcare infrastructure, and the expansion of dental workforce capacity (6). Dental insurance, public health programs, and subsidies play crucial roles in determining access to dental care, but inadequacies in these areas can lead to significant barriers for many individuals. Dental insurance often dictates whether patients can afford necessary treatments, with many insurance plans providing limited coverage for essential dental services, leading to high out-of-pocket costs that deter individuals from seeking care (28). Inadequate dental insurance coverage is a significant barrier, especially for low-income families and individuals without employer-sponsored plans. Public health programs are intended to bridge the gap in access to care by providing basic dental services to underserved populations (29). However, these programs are frequently underfunded and unable to meet the growing demand, leaving many without adequate care. Moreover, the lack of comprehensive public health initiatives focused on oral health exacerbates disparities, especially in rural and economically disadvantaged areas. Subsidies and financial assistance programs are designed to make dental care more affordable, but their insufficiency often means that the most vulnerable populations are left without the necessary support to access care (30). Insufficient subsidies fail to cover the full spectrum of dental services, leading to untreated conditions and worsening oral health.

The urban-rural divide and the disparities between developed and developing countries create significant challenges in accessing dental care globally. In developed countries like the U.S., there are pronounced differences in dental care availability between urban and rural areas (31). Urban areas typically have a higher concentration of dental professionals and better infrastructure, while rural areas suffer from a lack of providers and facilities. For instance, underserved populations such as Medicaid beneficiaries often face limited access to dental providers due to low reimbursement rates, making it difficult for them to receive necessary care (32). In contrast, developing countries experience more severe challenges. In Sub-Saharan Africa, for example, there is an acute shortage of dental professionals, with some countries having only one dentist per 150,000 people (32). This extreme

scarcity leads to high unmet needs for dental care and significant public health challenges. The lack of dental schools and training programs, inadequate funding, and poor infrastructure further exacerbate these issues. Moreover, while developed countries may struggle with cost barriers and insurance coverage issues, they generally have better preventive and curative care facilities. Developing countries, however, often lack basic dental care services, leading to higher rates of untreated dental conditions and worse overall health outcomes. Overall, addressing these disparities involves a multifaceted approach, including enhancing workforce capacity, improving infrastructure, increasing funding, and implementing effective health policies. By focusing on these areas, efforts can be directed towards the reduction of the global burden of oral diseases and the assurance of equitable access to dental care for all populations. A comprehensive approach, including increased investment in dental healthcare infrastructure, expansion of the dental workforce capacity, and the implementation of effective public health campaigns, is required. Preventive measures and education initiatives should be emphasized to mitigate the incidence of oral diseases. Furthermore, collaborations with NGOs, international organizations, and the dental industry are essential to address these challenges.

3.6. Prevention and Public Health Initiatives

Preventive dentistry is a cornerstone of maintaining oral health and overall well-being. By focusing on early detection and intervention, dental professionals can help patients avoid more severe and costly treatments in the future. Preventive strategies encompass routine dental visits, professional cleanings, fluoride applications, the use of dental sealants, and educating patients about effective oral hygiene habits (2). Preventive dentistry offers numerous key benefits, including the early detection of dental issues like cavities, periodontal disease, and oral cancer, which can be treated more effectively when identified at an early stage. This proactive approach can lead to significant cost savings by reducing the need for extensive and expensive treatments (33). Moreover, maintaining good oral health is crucial for overall well-being, as it is linked to a reduced risk of systemic conditions such as cardiovascular disease and diabetes. Additionally, preventive dentistry emphasizes the importance of educating patients on proper brushing, flossing, and dietary habits, empowering them to maintain good oral health at home (34).

3.6.1. Water Fluoridation

Water fluoridation is the controlled addition of fluoride to a public water supply to reduce dental caries risk. It is regarded as one of the most economical ways to provide fluoride to the entire community, irrespective of age, education, or income. Studies have shown that water fluoridation significantly reduces the prevalence of dental caries in children and adults (35, 36).

3.6.2. School Dental Health Programs

School dental health programs aim to provide preventive dental care and education to children while they are in school. These programs often include dental screenings, fluoride varnish applications, dental sealants, and oral health education(37). By targeting children, these programs help establish good oral hygiene habits early in life and reduce the risk of dental caries and other oral diseases.

3.6.3. Community-Level Educational Interventions

Community-level educational interventions play a pivotal role in improving public health by addressing various preventable conditions. These interventions focus on educating individuals and communities about key health behaviors and risks, aiming to foster healthier lifestyles and prevent diseases. By targeting specific health issues such as oral hygiene, sugar intake, and tobacco use, these programs seek to reduce the prevalence of related health conditions and improve overall community well-being. They utilize a range of strategies, including school-based programs, public awareness campaigns, and support initiatives, to reach diverse populations and promote sustained behavior change. Below are detailed examples of effective educational interventions in promoting oral hygiene, reducing sugar intake, and supporting tobacco cessation.

3.6.4. Promoting Oral Hygiene

Education is fundamental in promoting oral hygiene by teaching individuals proper brushing and flossing techniques, the importance of regular dental check-ups, and the impact of diet on oral health. School-based programs and community initiatives often include interactive sessions, demonstrations, and distribution of educational materials to engage children and adults alike. For instance, Shirahmadi et al. (38) demonstrated that theory-based educational interventions significantly improved oral health behaviors among elementary school students.

3.6.5. Reducing Sugar Intake

Educational programs designed to reduce sugar intake primarily aim to raise awareness about the health risks associated with excessive sugar consumption, such as obesity, diabetes, and dental caries. These programs often incorporate practical strategies for making healthier food choices, understanding food labels, and decreasing the consumption of sugary beverages (39). In 2015, the World Health Organization issued guidelines and recommendations to reduce free sugar intake in order to prevent non-communicable diseases (NCDs) (40).

3.6.6. Tobacco Cessation

Education is also a key component in tobacco cessation efforts. Health professionals are trained to provide evidence-based information and support to individuals trying to quit smoking (38). Programs like "Rx for Change: Clinician-Assisted Tobacco Cessation" equip clinicians with the skills to assist patients in their quitting journey (41). The CDC offers various resources, including training videos and patient cessation materials, to help healthcare providers effectively support tobacco cessation (42).

3.7. Global Health Policies and Initiatives

Oral health as a critical component of overall well-being often receives less attention than other aspects of health care. Recognizing its importance, various global health policies and initiatives have been developed to address the challenges and improve oral health outcomes worldwide. These efforts are spearheaded by the World Health Organization (WHO) and involve numerous international partners, civil society organizations, and the private sector. By integrating oral health into broader health agendas, these initiatives aim to provide equitable access to oral health services, reduce the burden of oral diseases, and ultimately improve the quality of life for people around the world.

The World Health Organization (WHO) introduced the Global Strategy and Action Plan on Oral Health 2023–2030, which presents a detailed framework of key actions for Member States, the WHO Secretariat, global partners, civil society, and the private sector to ensure equitable access to oral health for everyone by 2030 (43). The plan includes 11 global targets to track progress and emphasizes integrating oral health into non-communicable disease (NCD) and universal health coverage (UHC) benefit packages. Additionally, the WHO's *Global Oral Health Status Report 2022* provides a detailed overview of the global oral disease burden, highlighting the challenges and opportunities to accelerate progress towards universal coverage for oral health (15). It underscores the need for political action and resource mobilization to improve oral health outcomes, especially in low- and middle-income countries.

International policies and partnerships play a significant role in enhancing oral health outcomes globally. For instance, the first-ever global oral health meeting, hosted by the Government of Thailand, resulted in the *Bangkok Declaration on Oral Health*. This declaration commits over 110 countries to accelerate the implementation of the *Global Strategy and Action Plan on Oral Health 2023-2030*, aiming to recognize oral health as a fundamental human right and integrate it into primary health care and UHC packages (44). In India, Colgate-Palmolive launched the *Oral Health Movement*, empowering millions with AI-powered personalized dental screening in partnership with the Indian Dental Association (45). This initiative aims to raise awareness about oral health and provide free dentist consultations to those in need.

The Federation Dentaire Internationale (FDI) has several notable initiatives, including the *Sustainability in Dentistry Initiative* launched in 2021, which aims to reduce the environmental impact of dentistry by collaborating with industry partners to develop a Sustainability Code of Practice (46). Another initiative is *World Oral Health Day*, celebrated annually on March 20th, which unites efforts to reduce the global burden of oral diseases and promote good oral health practices (47). The FDI's *Organizational Strategy for 2024-2027* focuses on knowledge exchange, advocacy, and innovation to achieve optimal oral health globally (48).

Other global organizations contributing to oral health improvement include the International Association for Dental Research (IADR), which supports research to enhance oral health and quality of life through dental, oral, and craniofacial research (49). The International Dental Federation (IDF) promotes oral health and quality of life through advocacy, education, and the dissemination of best practices in dentistry (50), while the Pan American Health Organization (PAHO) implements programs to improve oral health in the Americas, focusing on prevention, treatment, and education (51).

The United Nations' Sustainable Development Goals (SDGs), particularly “Goal 3: Good Health and Well-being”, are integral to improving oral health outcomes (52). Goal 3 aims to ensure healthy lives and promote well-being for all ages, encompassing a wide range of health priorities, including reproductive, maternal, newborn, child and adolescent health, communicable and non-communicable diseases, and UHC. Oral health is essential to overall health and well-being, with poor oral health leading to serious issues such as heart disease, diabetes, and respiratory infections. Addressing oral health is crucial for achieving the targets under Goal 3, such as reducing premature mortality from NCDs and promoting mental health and well-being.

Several studies have emphasized the connection between oral health and SDGs. For example, Abodunrin et al. conducted a scoping review that mapped the research linking oral health and sustainable development goals (53). The review found that oral health is closely related to several SDGs, including SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), and SDG 5 (Gender Equality). The study highlights the need for integrated oral health care, dental education on the SDGs, and improved access to universal health care.

The *Alliance for a Cavity-Free Future (ACFF)*, a global non-profit organization established in 2010, is dedicated to reducing dental caries in children and promoting oral health worldwide (54). The ACFF aims to ensure every child born after 2030 remains cavity-free throughout their lifetime. Key initiatives include *World Cavity-Free Future Day*, launched in 2016, which raises global awareness about dental caries and promotes best practices for prevention and management, and the *Global Consensus for a Cavity-Free Future*, published by the ACFF Taskforce in 2021, outlining optimal measures to prevent and manage dental caries. The ACFF operates through 29 local chapters across six continents, tailoring their goals to local needs while working towards the global mission of the ACFF. By promoting healthy brushing habits, reducing sugar intake, and advocating for fluoride use, the ACFF aims to make cavities a thing of the past.

3.8. Innovative Solutions and Technology

Innovation and technology are revolutionizing the field of oral health, offering new solutions to long-standing global challenges. From cutting-edge diagnostic tools and AI-driven treatment plans to advanced materials and telehealth services, these advancements are enhancing the accuracy, accessibility, and effectiveness of dental care. By leveraging innovative technologies, healthcare providers can offer personalized and preventive treatments, thus reducing the prevalence of oral diseases and improving overall health outcomes. Moreover, these advancements are bridging gaps in care, particularly in underserved communities, making quality oral healthcare more attainable worldwide. As we embrace these transformative changes, the future of oral health looks

promising, with potential for significant improvements in both individual and public health.

3.8.1. Artificial Intelligence (AI)

Artificial intelligence (AI) is making significant strides in revolutionizing dental diagnostics and treatment planning. By harnessing the power of sophisticated algorithms, AI is capable of analyzing radiographs, intraoral scans, and other diagnostic images with remarkable precision. These algorithms can detect subtle patterns and anomalies that might be missed by the human eye, leading to the early identification of dental conditions such as cavities, gum disease, and oral cancer (55). In the realm of cavity detection, AI can identify the smallest signs of decay before they become visible to the naked eye, enabling interventions at a much earlier stage. This early detection can prevent the progression of cavities, thereby reducing the need for more extensive and invasive treatments such as root canals or extractions. Similarly, AI can assess the health of gum tissues, identifying early signs of periodontal disease. By detecting gum disease in its initial stages, patients can receive timely treatments that prevent the condition from worsening, ultimately preserving the health of their teeth and gums (1). AI's capabilities extend to the detection of oral cancers, which are often challenging to diagnose in their early stages. Through the analysis of imaging data and the identification of atypical tissue patterns, AI can assist clinicians in spotting potential malignancies sooner, leading to earlier interventions and significantly improving patient prognosis. Early detection of oral cancer is crucial, as it greatly enhances the chances of successful treatment and survival (56). Moreover, AI is transforming treatment planning by providing dental professionals with comprehensive, data-driven insights. AI systems can analyze a vast array of patient data, including medical histories, genetic information, and lifestyle factors, to generate personalized treatment plans. These plans are tailored to the unique needs of each patient, ensuring that they receive the most effective and appropriate care. For instance, AI can recommend specific preventive measures, such as fluoride treatments or dietary modifications, based on individual risk factors (57). Furthermore, AI-powered tools are enhancing patient education and engagement. Virtual assistants and chatbots can provide patients with personalized advice, reminders for oral hygiene practices, and information about their treatment plans. This proactive approach empowers patients to take an active role in their oral health, leading to better compliance and improved overall outcomes (58).

3.8.2. 3D Printing

3D printing technology is revolutionizing the dental industry by enabling the creation of highly precise, custom dental prosthetics, such as crowns, bridges, dentures, and orthodontic appliances. This advanced technology allows for the fabrication of dental prosthetics with unprecedented accuracy and detail, tailored to the specific anatomy and needs of each patient. By utilizing digital scans of the patient's teeth and oral structures, dental professionals can design and produce prosthetics that fit perfectly, ensuring optimal comfort and functionality (59). Moreover, 3D printing significantly decreases the turnaround time for producing dental prosthetics. Traditional methods of creating crowns, bridges, and other dental appliances often involve multiple appointments and lengthy waiting periods as molds are made, sent to a lab, and manually crafted. In contrast, 3D printing streamlines this process, allowing for the rapid production of prosthetics within a matter of hours or days. This efficiency not only reduces the number of visits required for patients but also enables dental practices to serve more patients in less time (60). The accessibility of dental care is also improved through the use of 3D printing technology. The cost of producing dental prosthetics is lowered, as the need for extensive manual labor and expensive materials is reduced. This makes high-quality dental care more affordable and accessible to a broader population, including those in remote or underserved areas. Furthermore, the ability to produce custom prosthetics on-site or nearby eliminates the need for outsourcing, reducing transportation costs and delays (61).

3.8.3. Tele-dentistry

Tele-dentistry leverages the power of modern technology, utilizing video conferences, digital imaging, and other remote communication tools to provide dental consultations and treatments without the need for in-person visits. This innovative approach significantly enhances the accessibility and convenience of dental care, particularly for individuals living in remote or underserved areas where access to traditional dental clinics is limited (62). Through video conferences, dental professionals can conduct real-time consultations with patients, visually examining their oral health conditions and discussing symptoms and concerns. This interaction allows dentists to offer timely advice, diagnose issues, and develop treatment plans from a distance. For instance, patients can use their smartphones or other digital devices to share images or live video feeds of their oral cavity, enabling the dentist to assess conditions such as tooth decay, gum disease, or oral lesions with considerable accuracy (63). Digital imaging further complements tele-dentistry by allowing patients to send high-quality images of their teeth and gums to their dental providers. These images can be taken using intraoral cameras or other digital devices and provide detailed views that are essential for accurate diagnosis and treatment planning. Dentists can review these images, annotate them, and share their findings with patients, ensuring a thorough understanding of their oral health status. One of the most significant advantages of tele-dentistry is its ability to ensure continuous access to dental care during public health crises, such as pandemics, natural disasters, or other emergencies that may disrupt normal healthcare services. During such times, in-person dental visits might be risky or impractical, but tele-dentistry ensures that patients can still receive professional dental advice and care (64). This continuity of care is vital for managing chronic dental conditions, preventing complications, and maintaining overall oral health. Tele-dentistry also plays a crucial role in public health initiatives by facilitating preventive care and education. Dental professionals can use remote platforms to conduct virtual workshops, webinars, and informational sessions on oral hygiene practices, dietary recommendations, and disease

prevention (65). This outreach is particularly beneficial in areas where dental education and awareness are lacking, empowering communities with the knowledge to maintain better oral health. Moreover, tele-dentistry can reduce the overall cost of dental care by minimizing the need for physical infrastructure, travel expenses, and time off work for patients. This cost-effectiveness makes dental services more affordable and accessible, encouraging more individuals to seek professional care (64).

3.8.4. Digital Radiography

Digital radiography is transforming the field of dental diagnostics by offering high-resolution images that are far superior to traditional X-rays. This cutting-edge technology uses digital sensors to capture detailed images of teeth, bones, and soft tissues in the mouth, which can be viewed immediately on a computer screen. One of the most significant advantages of digital radiography is its ability to produce clearer and more precise images, which greatly enhances the ability of dental professionals to identify and diagnose dental issues quickly and accurately (66). The precision of digital radiography means that even the smallest dental problems, such as early-stage carious lesions, fractures, or infections, can be detected with greater accuracy. This early detection is crucial for prompt treatment, preventing the progression of dental diseases, and ultimately preserving the patient's oral health. For instance, subtle changes in bone density that indicate the onset of periodontal disease can be identified much earlier, allowing for more effective interventions. Another critical benefit of digital radiography is the significant reduction in radiation exposure compared to conventional X-ray methods (67). This is particularly important for patients who require frequent imaging, such as those undergoing orthodontic treatment or monitoring for chronic conditions. By minimizing radiation exposure, digital radiography not only improves patient safety but also makes it more feasible to conduct regular check-ups and follow-up assessments. Digital radiography also enhances patient comfort in several ways. The process is quicker and less invasive, as digital sensors are more compact and easier to position in the patient's mouth compared to traditional film plates. This results in a more pleasant experience, especially for patients who may have difficulty tolerating the older, bulkier equipment. Additionally, the immediate availability of digital images allows for faster and more efficient consultations (66). Dental professionals can review the images with patients in real-time, explaining the findings and discussing treatment options right away. This transparency fosters better communication between the dentist and the patient, empowering patients to make informed decisions about their oral health care. Furthermore, digital radiography integrates seamlessly with electronic health record systems, enabling better storage, retrieval, and sharing of patient information. This integration facilitates comprehensive patient management, as dentists can easily access previous images for comparison and track the progress of treatments over time.

3.9. The Impact of COVID-19 on Global Oral Health

The COVID-19 pandemic has had a profound impact on dental care and oral health globally. With the widespread closure of dental practices and the reduction of routine dental services to emergency-only care, many individuals experienced delays in receiving necessary treatment. This disruption has led to an increase in untreated dental issues, such as tooth decay and gum disease, and has highlighted the importance of preventive care and access to dental services. Additionally, the pandemic has underscored the need for innovative solutions, such as tele-dentistry, to ensure continuous access to dental care during public health crises. Several case studies and investigations have documented these impacts. For instance, a retrospective study conducted at a dental care university referral center in Madrid found that during the first wave of the pandemic, 58.67% of conservative treatments and 47.45% of periodontal treatments were not performed (68). This has increased the risk of tooth loss in adults. Another study from Basel, Switzerland, showed that urgent dental care provision involved intraoral radiographs more frequently before the lockdown, while aerosol-generating procedures dropped significantly during the lockdown (69). Additionally, a scoping review highlighted that the pandemic impacted oral health at the individual level, with changes to the provision of emergency dental services, routine oral health services, and oral hygiene maintenance at home (70).

Many dental practices were closed or operated with reduced hours, limiting access to routine dental care. Emergency and urgent services were prioritized, but routine check-ups and preventive care were significantly reduced. This restriction in services was a crucial factor contributing to the overall decline in oral health during the pandemic. A multi-country survey conducted by Abdelrahman et al. assessed the extent of dental practice closures during the first wave of the pandemic (71). The study found that 75.9% of dentists reported practice closures, with a significantly higher percentage in the private sector compared to the non-private sector. The closures were associated with professional, practice-related, and country-level structural factors. Dentists in non-private rural areas and those in hospitals reported a lower likelihood of closure, while those in academia reported a higher likelihood. Moreover, fear of contracting COVID-19 led many patients to avoid or delay dental visits. This reluctance was particularly pronounced among vulnerable populations, who were already at higher risk of severe outcomes from COVID-19. A study conducted by Majeed et al. (72) assessed the fear and perception of people visiting dentists during the COVID-19 pandemic. The cross-sectional study included 407 participants from various demographics who had visited dental clinics for treatment. The results showed that due to the contagious nature of COVID-19, a significant number of patients reported fear and reluctance to visit dentists for non-emergency treatments. This fear was particularly pronounced among vulnerable populations, such as the elderly and those with pre-existing health conditions, who were already at higher risk of severe outcomes from COVID-19.

The lack of routine dental care led to an increase in untreated dental conditions, such as carious lesions and periodontal diseases. The pandemic highlighted the importance of

preventive care in maintaining oral health. Without regular check-ups, minor dental issues often went unnoticed and untreated, evolving into more severe conditions requiring more extensive treatment. Populations already at higher risk for oral diseases experienced greater challenges during the pandemic. These groups faced increased barriers to accessing dental care and were more likely to suffer from oral health issues. The pandemic amplified existing disparities in oral health, underlining the need for targeted interventions to ensure equitable access to dental care.

During the pandemic, the use of tele-dentistry increased, allowing for remote consultations and triage. For example, A study by the Italian scientific dental association highlighted the adoption of teledentistry as a key strategy to manage patients' oral health while minimizing the risk of virus transmission (73). The study found that teledentistry allowed for remote consultations and triage, enabling dentists to provide preliminary diagnoses and treatment plans without requiring in-person visits. This approach helped maintain continuity of care and reduced the burden on dental practices. The use of telemedicine platforms, such as Attend Anywhere and WhatsApp, facilitated communication between dentists and patients, ensuring that urgent cases were addressed promptly while routine check-ups were conducted remotely. The implementation of tele-dentistry in Italy demonstrated its potential to improve the provision of dental services, especially during periods of restricted access. The study emphasized the need for sound legislation and infrastructure to support the widespread adoption of tele-dentistry, particularly in developing countries.

The pandemic created a backlog of dental cases that needed to be addressed once practices reopened. This backlog has led to longer wait times for patients seeking dental care, putting additional strain on dental services and potentially delaying necessary treatments further (74). Some regions have implemented policy changes to improve access to dental care, such as the NHS dental recovery plan in the UK (5). These initiatives aim to address the long-term impacts of the pandemic on oral health by increasing funding for dental services, expanding tele-dentistry programs, and promoting preventive care.

The COVID-19 pandemic has caused a significant shift in patient behavior due to fear of infection and the economic downturn (75). Patients have become more cautious about visiting dental practices, prioritizing their safety and financial stability. Many patients have postponed or canceled routine dental check-ups and cleanings to minimize potential exposure to COVID-19. This has led to an increase in untreated dental issues and a backlog of cases. Patients are more likely to seek dental care only for urgent or emergency situations, such as severe pain or infection. This trend has resulted in a decline in preventive care and early intervention.

4. Conclusion

This review highlights the critical connection between oral and systemic health, emphasizing the disparities in access to dental care, particularly in low- and middle-income countries. The need for integrated, equitable, and innovative approaches to address these global health challenges is evident. Public health initiatives, preventive strategies, and the adoption of advanced technologies such as tele-dentistry and artificial intelligence are paramount. The impact of the COVID-19 pandemic underscored the urgency for resilient and adaptable dental care systems. Moving forward, global health policies must prioritize oral health to achieve comprehensive well-being for all. Collaborative efforts, robust research, and policy frameworks will be pivotal in overcoming the current challenges and paving the way for a healthier future. This review advocates for sustained investment in innovative technologies and comprehensive public health strategies to ensure equitable access to dental care for all populations.

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Using artificial intelligence (AI)

It is declared by the author of this manuscript that no generative artificial intelligence (AI) or AI-assisted technologies were used to generate content, ideas, or theories during the writing process of this work. AI was utilized solely for the purpose of enhancing readability and refining language, and this use was under strict human oversight and control.

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