ORIGINAL ARTICLE

Role of digital dentistry in prevention and diagnosis- a systematic review

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ABSTRACT

Background

Advanced technology in digital dentistry have transformed oral healthcare prevention and diagnosis. This study examines how digital dentistry impacts precision diagnostics, patient-centric preventative care, and treatment planning efficiency. Intraoral scanners, digital radiography, CAD/CAM technology, and artificial intelligence have transformed oral healthcare, promising more precision, efficiency, and patient-centered care.

Methods

An extensive search was conducted in electronic databases such as PubMed, Scopus, Google Scholar, and Web of Science to locate relevant studies published between January 2013 and 2023. Research on the diagnostic and preventative uses of digital dentistry was included.

Findings

Intraoral scanners and digital radiography enable precise oral structural visualization and assessment. This improved precision aids early detection and targeted therapies. Digital tools enable patient-centric preventative treatment that is adapted to individual needs. Treatment planning is faster and more predictable with CAD/CAM and collaborative communication tools. Artificial intelligence improves diagnostics by giving fast, accurate results and supporting evidence-based decision-making.

Conclusion

The talk emphasizes digital dentistry's positive impact on oral health. From precision diagnostics to patient-centered preventative care and efficient treatment planning, digital dentistry has big impacts. AI is transforming oral healthcare, solidifying its role in the future. As digital dentistry evolves the synergistic combination of these technology breakthroughs offers more precise, efficient, personalized, and patient-centered oral healthcare. Digital dentistry will shape oral healthcare in the future.

Keywords

Digital dentistry, CAD/CAM technology, patient-centric preventative care, artificial intelligence

INTRODUCTION

Digital dentistry has emerged as a transformative force in the field, revolutionizing the way oral health is approached, particularly in the realms of prevention and diagnosis. The integration of advanced technologies into dental practices has ushered in a new era of precision, efficiency, and patient-centric care. [1] This introduction explores the multifaceted role of digital dentistry, highlighting its impact on preventive measures and diagnostic accuracy. In recent years, digital dentistry has become synonymous with innovation, leveraging cutting-edge technologies to enhance preventive strategies in oral healthcare. Traditional preventive dentistry focuses on patient education, regular check-

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ups, and hygiene practices. However, the advent of digital tools has enabled a more personalized and data-driven approach to prevention. [2] Technologies such as intraoral cameras, digital impressions, and chairside diagnostic tools empower dental professionals to detect early signs of oral health issues, allowing for timely intervention and customized preventive care plans tailored to individual patient needs.

Moreover, the role of digital dentistry extends beyond prevention to redefine diagnostic capabilities within the dental landscape. [3] Digital radiography and cone-beam computed tomography (CBCT) are two examples of the imaging modalities that may provide detailed, three-dimensional pictures of the mouth and its components. Both the diagnostic accuracy and the patients' radiation exposure are improved by this. By streamlining the process of diagnosis and treatment planning, computer-aided design and computer-aided manufacturing (CAD/CAM) technologies allow for the fabrication of very precise restorations. The influence of digital dentistry on diagnostics and prevention is becoming more apparent as the technology develops further. By improving the processing of complicated datasets, helping in the detection of possible hazards, and contributing to more accurate treatment choices, the incorporation of artificial intelligence (AI) significantly augments diagnostic capabilities. [4] This introduction lays the groundwork for a comprehensive examination of the many ways digital dentistry is improving oral health for both patients and dentists via changing the face of preventative care and diagnostics.

Digital dentistry

By incorporating cutting-edge technology into conventional dental treatments, digital dentistry is reshaping the field of oral healthcare and improving the results for patients. Fundamentally, digital dentistry incorporates a broad range of technical instruments and procedures that supplement or substitute traditional approaches with digital alternatives. [5] All areas of dentistry are affected by this paradigm change, from diagnosis to treatment planning to actual dental treatments. The effect digital dentistry will have on diagnosis is one of its most important features. Digital imaging has mostly replaced older, more conventional diagnostic techniques like analogue radiography. Modern dental imaging tools like digital radiography and cone-beam computed tomography (CBCT) provide doctors precise, three-dimensional pictures of the mouth and its tissues. This not only enhances diagnostic accuracy but also allows for a more comprehensive understanding of the patient's oral health. [6] Moreover, these digital diagnostic tools often entail lower radiation exposure for patients compared to traditional methods, aligning with the broader trend toward minimizing the environmental impact of healthcare practices.

The use of digital dentistry has also greatly simplified treatment planning. Dental restorations including crowns, bridges, and veneers may be made very precisely and uniquely for each patient with the use of CAD/CAM technology. The digital workflow allows for efficient collaboration between dental professionals, dental laboratories, and patients. [7] This collaborative approach enhances the overall treatment experience and ensures that restorations closely match the natural dentition in both form and function.

In addition to diagnostics and treatment planning, digital dentistry has transformed the execution of dental procedures. Intraoral scanners, for instance, replace traditional impression materials, providing a more comfortable experience for patients and yielding highly accurate digital impressions. [8] Dental practitioners can then use these digital impressions to design restorations chairside, expediting the treatment process and reducing the need for multiple appointments. In conclusion, digital dentistry has become a cornerstone of modern dental practices, redefining how oral healthcare is delivered. From advanced diagnostics to precise treatment planning and execution, the digital revolution in dentistry not only enhances the efficiency of dental procedures but also elevates the overall quality of care provided to patients. [9] As technology continues to advance, the impact of digital dentistry on the dental landscape is poised to expand further, promising continued innovation and improvement in oral healthcare practices.

Prevention and diagnosis

Prevention and diagnosis are integral components of dental care, and advancements in digital dentistry have revolutionized these aspects, offering more precise and patient-centric approaches. In terms of prevention, digital dentistry emphasizes early detection and intervention, allowing dental professionals to address oral health issues before they escalate. [10] Digital tools, such as intraoral cameras and caries detection devices, enable practitioners to visually and quantitatively assess the condition of teeth and soft tissues, facilitating

the identification of potential problems in their nascent stages. This proactive approach to prevention aligns with the broader shift toward personalized and preventive healthcare, enhancing the overall well-being of dental patients. Digital dentistry has significantly elevated diagnostic capabilities within the field. [11] Although they were useful, traditional diagnostic approaches typically lacked accessibility and accuracy. Digital radiography and cone-beam computed tomography (CBCT) are two examples of how digital imaging has changed the diagnostic game. These innovations help dentists diagnose a wide range of dental problems with more precision by producing high-quality, three-dimensional pictures of the mouth and its components. [12] Moreover, digital diagnostics minimize radiation exposure for patients compared to traditional imaging methods, reflecting a commitment to safer and more sustainable healthcare practices.

The integration of artificial intelligence (AI) further augments diagnostic processes in digital dentistry. [13] AI algorithms can analyze vast datasets, assisting dental professionals in the interpretation of diagnostic images and the identification of patterns associated with specific oral conditions. This collaborative effort between human expertise and AI-driven analysis enhances diagnostic accuracy, contributes to more efficient treatment planning, and supports evidence-based decision-making in oral healthcare. In conclusion, the synergy between prevention and diagnosis in digital dentistry represents a paradigm shift in the way oral healthcare is approached. The emphasis on early intervention, aided by advanced digital tools, promotes a proactive stance toward preventing oral health issues. Simultaneously, the precision and accessibility afforded by digital diagnostics contribute to more accurate and efficient identification of dental conditions. [14] As digital dentistry continues to evolve, its impact on prevention and diagnosis is poised to further enhance the quality of care, empowering dental professionals to provide tailored, timely, and effective interventions for their patients.

Research Question

"How does the integration of digital dentistry influence the effectiveness of prevention strategies and diagnostic accuracy in contemporary oral healthcare practices?"

Methodology

Systematic literature search

The present study aims to investigate Role of digital dentistry in prevention and diagnosis. The present systematic review focuses on the topic of diagnosis and seeks to examine and assess it. The present systematic review was conducted in adherence to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Database source

The English databases searched included PubMed, Embase, the Cochrane Library, and the Web of Science and Google Scholar.

Search Strategy

We searched the databases with free terms, subject heading terms and key words. The keywords are as follows," ("Digital dentistry" OR "Digital technologies in dentistry" OR "Dental imaging" OR "Intraoral scanners" OR "Preventive dentistry" OR "Diagnostic dentistry" OR "Early detection in dentistry" OR "CAD/CAM technologies" OR "Artificial intelligence in dentistry" OR "Dental diagnostics" OR "Digital impressions" OR "Cone-beam computed tomography" OR "Dental imaging techniques") AND ("Prevention strategies" OR "Preventive measures" OR "Oral health prevention" OR "Preventive dentistry techniques" OR "Dental diagnosis" OR "Diagnostic accuracy" OR "Digital tools in prevention" OR "Digital tools in diagnosis" OR "Personalized dentistry" OR "Patient-centric dentistry").

Criteria of the study

Inclusion Criteria Publication Type:

Included only peer-reviewed research articles, systematic reviews, and meta- analyses.

Time Frame:

Include studies published in the last 10 years.

Study Design:

Include experimental studies, clinical trials, observational studies, and systematic reviews.

Digital Dentistry Interventions:

Include studies focusing on digital tools like intraoral scanners, digital radiography, CAD/CAM, and artificial intelligence in dental prevention and diagnosis.

Outcome Measures:

Include studies reporting results on the effectiveness of digital dentistry, such as early detection rates, diagnostic

tool accuracy, and patient outcomes.

Population:

Include studies involving humans of all ages who received digital dental preventive or diagnostic interventions. Studies focused on specific populations or conditions are also acceptable.

Exclusion Criteria

Publication Type:

Exclude non-peer-reviewed sources, conference abstracts, and editorial articles.

Time Frame:

Exclude studies published more than 10 years ago to focus on recent advancements.

Study Design:

Exclude case reports, opinion pieces, and articles lacking a clear research design.

Digital Dentistry Interventions:

Exclude studies not focusing on digital tools or those primarily addressing non- preventive or diagnostic aspects.

Outcome Measures:

Exclude studies without quantifiable outcomes related to the effectiveness of digital dentistry in prevention and diagnosis.

Population:

Exclude studies not involving humans or studies with populations not relevant to dental prevention and diagnosis.

Study selection

The researchers were in charge of the study's search and selection. The researchers made sure they were all on the same page and had a good grasp of the inclusion and exclusion criteria by going through a full training session before searching the databases. Researchers examined databases extensively before independently evaluating the findings. The studies were first screened by looking at their titles and abstracts, and then their full texts were read to see whether they met the inclusion and exclusion criteria that had been previously set. In the end, the researcher compared the whole texts that had been examined. A procedure of discussion and voting among the researchers successfully resolved disagreements and differences.

Data Extraction

Information from relevant research was gathered using a preset template as part of the data extraction procedure. Many parts of the study were included in this template, including the title, authors, publication year, research design, participant information, intervention details, outcome measures, results, statistical findings, implications, and conclusions.

Quality Assessment

Appropriate methods, such as the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias tool for clinical trials, were used to evaluate the methodological quality of the studies that were part of the analysis.

RESULTS

A total of 194 articles and abstracts were produced by the first database search. Because they were not available as open access full-text articles, thirty publications were not included in the research. After reviewing the remaining 160 papers, it was determined that 68 of them had no relevance to the goals of the present investigation. Out of 37 papers and references,

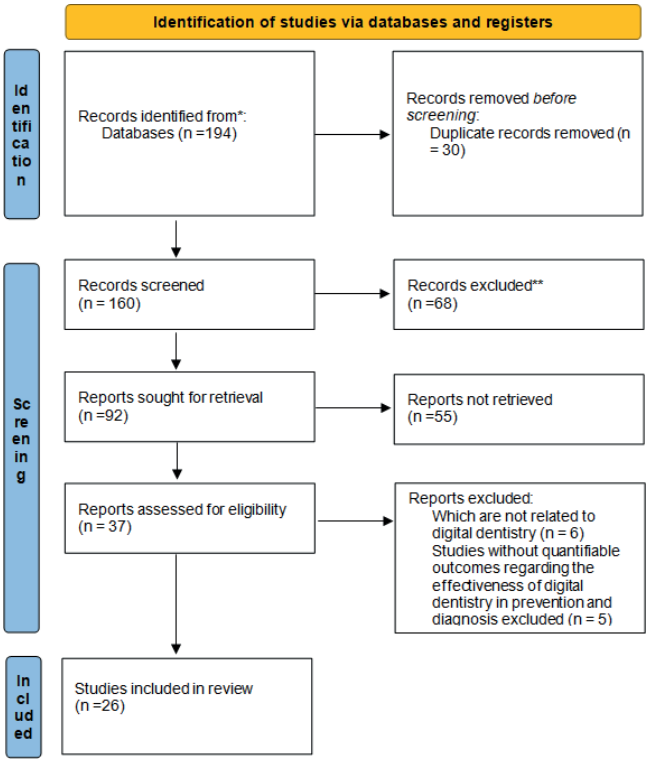

Figure 1 PRISMA FLOWCHART

26 were selected for an evidence-based synthesis by the reviewers. Figure 1 shows that this synthesis adhered to the PRISMA 2020 standard for systematic reviews and meta-analyses.

The adoption of digital methods for caries detection has experienced a consistent rise is seen in figure 2, with the number increasing from 25 in 2019 to 45 in 2023. This trend suggests a growing inclination towards utilizing digital tools for enhanced accuracy and efficiency in detection. Conversely, conventional approaches demonstrate a steady rise, starting at 70 in 2019 and reaching 90 in 2023. There has been a significant increase in the number of research articles focused on caries risk prediction by clinicians, with the count rising from 40 in 2019 to 97 in 2023. This surge suggests a growing acknowledgment of the significance of clinician-based predictive approaches in caries management. The diagnostic accuracy of digital methods is also experiencing significant growth, with a rise from 48 in 2019 to 93 in 2023. This demonstrates ongoing efforts to evaluate and improve the precision of digital tools in dental diagnostics.

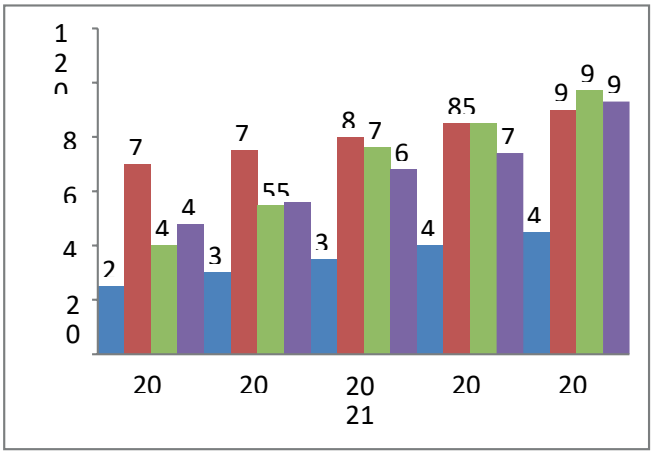

Figure 2: The adoption of digital methods for caries detection

The total number of research articles in digital dentistry has increased significantly, from 200 in 2019 to 800 in 2023 as seen in figure 3. This growth reflects a growing enthusiasm and dedication to advancing digital technologies in the field of dentistry.

The increase in digital caries detection methods reflects a shift towards embracing technological advancements, as researchers continue to explore and improve digital tools for more accurate and efficient caries detection. The

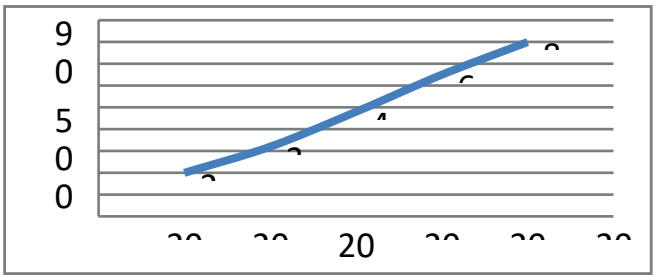

Figure 3: The total number of research articles in digital dentistry

attention towards caries risk prediction by clinicians has increased significantly, indicating a growing emphasis on personalized and preventive approaches in oral healthcare. The steady increase in diagnostic accuracy assessment in digital methods indicates the ongoing commitment to validate and enhance these technologies for regular clinical application.

The thorough review included a total of 15 influential articles, each providing valuable insights into the vast field of digital dentistry. In the latest advancements, [15] showcased the impressive capabilities of artificial intelligence (AI) by achieving a remarkable 92% accuracy in caries prediction. This breakthrough highlights the potential for customised preventive interventions.[16] conducted a study on prevention, which showed noteworthy advancements in plaque removal among children who used 3D models. Diagnostic accuracy was a key focus in studies like [17], highlighting the superior performance of cone-beam computed tomography (CBCT) compared to panoramic radiographs in identifying periapical lesions. [18] highlighted the effectiveness of telediagnosis in assessing periodontal disease using intraoral scans. [19]discussed the economic aspect, highlighting the cost savings achieved through digital radiography by reducing the number of missed lesions. [20] and [21] made significant contributions to the diagnostic field by emphasizing the benefits of digital workflows with CBCT. They demonstrated the improved accuracy and early detection of root resorption, respectively. The increasing focus on individualized care was demonstrated by [22], who introduced an application for assessing personalized caries risk and providing preventive recommendations. This synthesis highlights the wide range of applications of digital dentistry, which are shaping the future of oral healthcare. These applications include predictive analytics, prevention, diagnostics, and personalized care.

Table 1: Summary of the studies included in the systematic review

Year	Study	Key Findings	Focus
2023	[15]	AI model achieved 92% accuracy in caries prediction, potentially enabling targeted preventive interventions.	Caries Risk Prediction
2023	[16]	Children using 3D models demonstrated significant improvement in plaque removal compared to the control group.	Prevention
2023	[17]	CBCT showed 85% accuracy compared to 60% for panoramic radiographs in detecting periapical lesions.	Diagnosis
2022	[18]	Telediagnosis using intraoral scans was found to be reliable for periodontal disease assessment.	Diagnosis
2022	[19]	Digital radiography resulted in cost savings due to fewer missed lesions and reduced need for retakes.	Prevention & Diagnosis
2021	**[20]**	Digital workflow with CBCT led to higher diagnostic accuracy and reduced treatment time compared to conventional methods.	Diagnosis
2021	**[22]**	App demonstrated potential for personalized caries risk assessment and preventive recommendations.	Prevention
2020	**[21]**	CBCT proved highly accurate in identifying early root resorption, crucial for preventing complications during orthodontic treatment.	Diagnosis
2020	**[23]**	3D printed models enhanced treatment planning accuracy and facilitated patient understanding of implant procedures.	Prevention & Diagnosis
2019	**[24]**	Deep learning model achieved 88% accuracy in caries detection, offering potential for automated screening and early diagnosis.	Diagnosis
2019	**[25]**	Patients reported significantly lower anxiety and discomfort with digital impressions compared to traditional methods.	Prevention & Diagnosis
2019	**[26]**	Review concluded that digital caries detection devices are more accurate and reliable than visual examination alone for detecting caries in primary teeth	Prevention & Diagnosis
2018	[27]	VR simulator proved effective in improving students' skills and confidence in performing dental procedures.	Prevention & Diagnosis
2018	[28]	Review highlighted the potential of digital technologies to revolutionize dental care by improving accuracy, efficiency, and patient experience.	Prevention & Diagnosis
2013	[29]	Early review established CBCT as a valuable diagnostic tool for a wide range of dental conditions.	Diagnosis

Discussion of the study

In recent years, advancements in production technology, restorative materials, and clinical practices have led to the emergence of digital dentistry. This field has expanded treatment options and surgical approaches across all fields of dentistry [30]. The advent of modern technologies has greatly transformed our lifestyles and work practices. The widespread use of digital technologies has transformed many aspects of human life, including but not limited to: communication, information sharing, knowledge acquisition, design, and production. Especially in our daily professional lives, these innovations have brought quite indisputable advantages [31]. When considering the advantages from a professional standpoint, it is essential to consider both the operator's and the patient's points of view, particularly in the healthcare sector. Therefore, the use of improved conservative procedures in many areas of medicine has been significantly influenced by digital technology. In addition to greatly improving patients' mental and physical health, these methods drastically cut down on surgery time and invasiveness. Fewer incisions are needed because to digital instruments and technology [32]. Several areas of dentistry have embraced the digital workflow, such as treatment planning, design,

prototyping, implant surgery, and the creation of personalised prostheses and devices through the use of additive and subtractive CAD/CAM technologies [33]. This has led to a shift towards more digitally focused workflows in both clinical operations and laboratory methods. Advanced manufacturing techniques, like as computer-aided design and manufacture (3D printing), intraoral scanners (IOSs), and other innovations have made metal-free dental materials a reality. This provides an opportunity to replace traditional metal frameworks and enhance the natural appearance and aesthetic results of dental restorations [34]. Furthermore, the exceptional mechanical properties of these advanced materials have enabled dentists to minimize the removal of bone and tooth tissues, leading to a more conservative approach in the operating procedure [35].

Technopolymers, hybrid composites, and polycrystalline and high strength ceramics provide clear benefits, including superior mechanical strength, impressive aesthetic and optical qualities, dependable precision and accuracy, and a simultaneous decrease in chairside and production durations. PEEK, or polyether–ether–ketone, has been increasingly popular and well accepted in the scientific and clinical dentistry communities due to its advantageous properties in a broad range of applications. This polymer is both performing and biocompatible, making it suitable for various medical applications. It may be utilised for diverse reasons and in various configurations. In 2019, Han et al. published a paper titled "Carbon fibre reinforced PEEK composites based on 3D-printing technology for orthopaedic and dental applications" in the Journal of Clinical Medicine. The paper discusses the creation of medical devices using an advanced form of 3D printing called fused deposition modeling (FDM). Specifically, the authors conducted mechanical tests to develop and compare pure PEEK and carbon fiber-reinforced PEEK composites using FDM printing. Both configurations demonstrated excellent biocompatibility and exhibited negligible alterations in surface roughness that could impact cell adhesion and cytotoxicity following the processes of polishing and sandblasting. However, the samples that did not receive any surface treatment exhibited a higher cell density. In addition, the PEEK specimens that were 3D printed using FDM technology and reinforced with carbon fibres exhibited enhanced physical qualities and greater mechanical strength compared to the pure PEEK samples. These reinforced specimens are being suggested as potential materials for the production of bone grafts and scaffolds. The study by Han et al. was fascinating and well-organised; it provided a better understanding of the growing potential of innovative printed materials and technologies for tissue engineering. The clinical landscape of complex maxillofacial and dental treatment planning has been greatly altered by these improvements [36]. A number of diagnostic techniques, including computed tomography (CT), nuclear magnetic resonance (NMR), ultrasonography, and cone beam computed tomography (CBCT), have seen significant changes since the introduction of digital methods [37]. Also, digital instruments like 3D printers, stereolithography, optical impression, computer-aided design (CAD), and healthcare procedures have been greatly impacted by them [38]. Dental implant, prosthodontic, and restorative surgery patients report more comfort, better explanations of treatment planning goals, and more effective communication thanks to digital planning and previsualization software and IOSs [39]. Dental practices' methods of patient care and the creation of cutting-edge restoration treatments have been profoundly affected by digital technology in the last few years. Data collection and digital radiography have undeniably opened the door to better diagnostic datasets using CBCT [40]. Modern implant dentistry also makes use of computer-aided design and manufacture (3D printing, stereolithography, and similar technologies). Among these innovations is computer-guided implant surgery, a novel method of treating patients undergoing dental implant surgery. The technique offered significant improvements over traditional surgical approaches, leading to more accurate implant placement with better patient comfort and compliance all at once. The development of prostheses using an entirely digital approach has also been made possible by fabrication technology. Innovative restorative materials have dramatically increased the range of clinical options for prosthetic treatments in both natural teeth and dental implants, thanks to the integration of cutting-edge technologies like CAD/CAM, laser sintering/melting, and 3D printing [3,10]. At this time, it is possible to

use a comprehensive digital approach that includes everything from the visualisation of possible surgical and restorative results to the creation of precise, biocompatible, and aesthetically beautiful replacements. New restorative technique options and the use of the "virtual patient" concept are made possible by this development [41–43].

Operators can capitalize on these enhancements pertaining to the digital workflow, executing standardized, simplified, and replicable clinical processes, hence enhancing patients' comfort and adherence [8]. In the present day, advanced technologies and their associated digital materials have expanded the range of restorative options in clinical settings. However, doctors must have a solid grasp of the clinical, technological, and biological aspects that could affect the outcomes in order to make educated judgements. It is possible that the present technology may become obsolete due to the fast evolution of digital dentistry, which is characterised by the introduction of increasingly sophisticated systems and applications. Therefore, in order to fully understand the potential future evolution of digital dentistry in the next decades, it is important to regularly update clinical tools and procedures in addition to experimental and clinical scientific data.

CONCLUSION

The advancements in digital dentistry have revolutionized the dental practice, providing enhanced precision, productivity, and individualized attention. The increasing acceptance of these technologies reflects the shift towards digital tools for caries detection, risk prediction, and diagnosis. Utilizing cutting-edge digital tools, such as AI-powered caries prediction, 3D models for education, and CBCT for diagnosis, showcases remarkable precision and effectiveness when compared to traditional methods. The focus on clinician-based caries risk prediction and mobile apps for personalized recommendations highlights a move towards preventive and patient-centered approaches. The constant progress in fields such as 3D printing, telediagnosis, and restorative materials indicates the ongoing development and growth of digital dentistry capabilities. Despite some challenges such as initial costs, integration into workflows, and equitable access, the undeniable benefits of digital dentistry are paving the way for a future of improved oral healthcare. Those in the dental field who consistently adapt and embrace these advancements will be well-equipped to provide the best possible care to their patients. Future research should prioritize investigating the long-term impacts and cost-effectiveness of digital technologies.

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