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Original Research

Enhancing dental practice: cutting-edge digital innovations

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Digital technology offers many opportunities and challenges across various domains. **Aim:** This comprehensive review explores the transformative impact of digitalization on dental practices, encompassing digital Imaging, 3D printing, intraoral scanners, teledentistry, Artificial Intelligence, CAD-CAM technology, and virtual reality. **Methods:** A rigorous search was conducted across various electronic bases, including PubMed, Google Scholar, Scopus, and the National Center for Biotechnology Information (NCBI). The search employed keywords such as "Orthodontics," "Dental Health," "Dental Imaging," "CAD-CAM," "Digital Medicine," "Teleconsultation," "Intraoral Scanner," "Artificial Intelligence (AI)," "Digital Health," "Teledentistry," and "3D Dentistry." Papers published between 2017 and the present were considered, focusing on peer-reviewed journals and reviews providing comprehensive insights into digital dentistry. **Results:** The review highlights the diverse facts of digitalization in dentistry, emphasizing its potential benefits for patient practitioners and the dental industry. Digital impressions, 3D printing, and CAD-CAM are streamlining restorative dentistry. In orthodontics, digital models enable precise simulations. Artificial Intelligence promises more efficient diagnostics and treatment planning. **Conclusion:** Digital technology is poised to reshape dentistry, improving efficiency, patient outcomes, and practitioner experiences. However, challenges such as data security and ethical considerations must be addressed. The successful integration of digital dentistry into dental practice will require more research and innovation, even though this review offers a thorough overview of the field.

Keywords: Orthodontics. Radiography, dental, digital. Computer-aided design. Remote consultation.

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Introduction

Healthcare is undergoing a sweeping digital transformation, and digital dentistry is one increasingly prominent area. As digital health technologies revolutionise the medical landscape, their impact on oral healthcare is equally profound[1]. Digital dentistry harnesses the power of advanced Imaging, computer-aided design and manufacturing (CAD-CAM), telehealth, and artificial intelligence to redefine how dental care is delivered and experienced[1,2]. Digital dentistry encompasses tools and methods redefining dental care delivery, from precise 3D imaging and custom-made prosthetics to teledentistry consultations and data-driven treatment planning. These innovations are introducing a new era of precision, accessibility, and patient-centric care[2,3].

Dentistry has undergone a remarkable journey from its traditional roots to the digital era, one that game-changing technological developments have characterized. Early dentistry frequently needed more precision and relied on crude tools and visual examinations[4]. However, high-resolution images, 3D printing, and intraoral scanning have revolutionized the field since the introduction of digital technology. These developments have increased patient comfort and enhanced diagnostic accuracy[5,6]. Additionally, the management of dental practices has been streamlined by incorporating digital tools, freeing staff members to devote more time to patient care[5]. The transition from traditional to digital dentistry represents a notable change in how oral healthcare is provided and practiced, with significant ramifications for the field's future[4]. The dental and dentomaxillofacial fields can use the digital treatment workflow discussed here. However, the areas of implantology and restorative dentistry are most prominently used[7].

Digital dentistry, at its core, includes a variety of cutting-edge instruments and methods, such as CAD-CAM, 3D printing, Artificial Intelligence, augmented reality, and teledentistry[3,8]. Digital impression-taking has streamlined the process of creating dental restorations in restorative dentistry[9]. The availability of various CAM materials has improved laboratory processes and allowed for more effective and accurate same-day treatments. Digital models used in virtual setups for on-screen simulation of orthodontic procedures are just as precise as conventional techniques in orthodontics[9]. Transferring treatment plans utilizing guides, aligners, personalized computer-made appliances, and guided surgical techniques, such as tooth transplantation and piezo-assisted surgery, offers a more accurate and predictable result[10].

Despite the rapid advancements, several gaps still need to be addressed in the current research. While there is significant progress in areas like CAD-CAM and 3D printing, integrating augmented reality, virtual reality, and machine learning into dental practices is still in its infancy[6,8]. Moreover, the high cost of technology adoption, the need for specialized training, and concerns about potential technological errors present substantial barriers. Cybersecurity is another critical concern, as digital patient data and images are vulnerable to cyberattacks[11].

Additionally, professional unwillingness is due to fears of job displacement, which must be addressed by emphasizing that digital dentistry aims to support practitioners rather than replace them[12]. The impact of digitalization on patient-dentist

relationships, the roles within dental professions, and environmental effects are also under-researched areas. Digital innovations are transforming various sectors and dentistry is no exception. This review aims to provide a comprehensive understanding of how digital technology is transforming dentistry. The purpose of this review is to examine the integration of these innovations into dental practice and their potential benefits for patients and practitioners.

Materials and Methods

This review sought to answer the question, "How are digital innovations transforming dental practice, and what are the significant advancements and challenges associated with these technologies?". In order to complete this review, we combed through numerous current research papers and publications with a focus on innovation in the field of digital dentistry. We used electronic databases like the Institute of Electrical and Electronics Engineers (IEEE), Web of Sciences, Science Direct, Google Scholar, National Center for Biotechnology Information (NCBI), Scopus, and PubMed to gather pertinent information. Regarding incorporating digital dentistry into conventional dental practices, our study aimed to investigate perspectives, implementation, and potential future research directions. Specifically, we used the terms "Orthodontics," "Dental Health," "Dental Imaging," "CAD-CAM," "Digital Medicine," "Teleconsultation," "Intraoral Scanner," "Artificial Intelligence (AI)," "Digital Health," "Teledentistry," and "3D Dentistry," "3D Printing," "Digital Dentistry," "Digital Imaging". Figure 1 shows search items used in every database. Using proximity operators (NEAR, NEXT, WITHIN) and Boolean operators (AND, OR), we selected papers published between 2017 and the present.

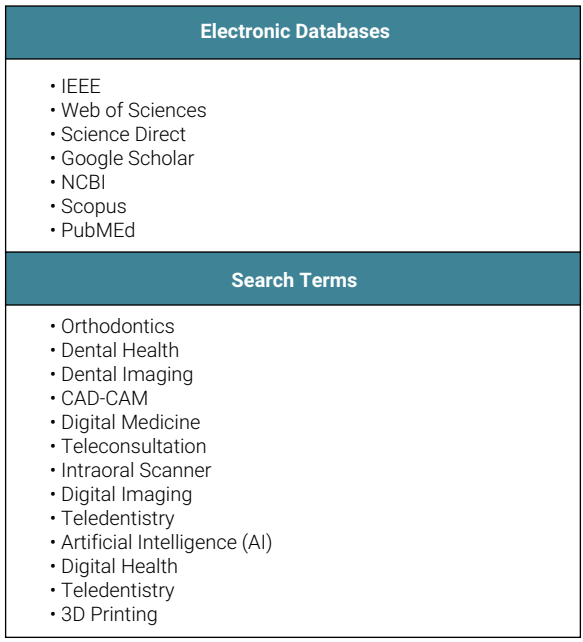

Figure 1. Search Terms and Databases

There were several stages to the research process. A thorough search across several databases was conducted first to find relevant publications examining article titles, abstracts, and index keywords. A secondary search across all databases using the identified keywords, index phrases, and MeSH terms, including those from MEDLINE. Additional studies were also sourced from the reference lists of included research papers and publications. Moreover, various databases were thoroughly searched using tools such as PubMed, Google Scholar, and Google to ensure the inclusion of all pertinent reports. Full-text access to relevant publications was obtained after a meticulous examination of their titles and abstracts for appropriate search terms. This review was conducted by a single author. It is important to note that this article is a review and may only encompass some of the intricacies of innovations in digital dentistry. Instead, we focused on incorporating the most significant and relevant studies within this domain.

Eligibility Criteria

The papers were selected based on the following inclusion and exclusion criteria.

Inclusion Criteria

Studies for this review were chosen based on the following criteria:

- Research on advancements in digital dentistry was taken into account.
- There were studies on CAD-CAM, 3D printing, teledentistry, Digital Imaging, and other pertinent technologies.
- Reviews that provided a thorough understanding of digital dentistry technologies were given priority.
- Various study designs were considered, including cross-sectional studies, systematic reviews, research articles, and randomised control trials, to ensure a complete understanding of the research criteria.

With a focus on exploring the use of the Metaverse in healthcare, immersive technologies, and their impact on digital health, these standards were applied in the selection process to ensure that relevant and peer-reviewed papers were included in the review.

Exclusion Criteria

The following criteria were used to exclude studies from the review:

- Papers that were written in languages other than English were excluded.
- The review did not consider any papers that did not focus on innovations in digital dentistry.
- Studies with goals unrelated to digital dentistry were excluded.
- Studies that lacked evidence to support the predetermined conclusions were excluded.
- Additionally, studies with topic-related titles but irrelevant content were omitted from the review.

Results

This comprehensive review will discuss the transformation of technological advancements in dental education and research and the enhancement of patient care and treatment outcomes. A summary of all the studies is given in Table 1.

Table 1. Summary of Related Studies

Title	Author	Year	Key Findings
The digital patient – Imaging science in dentistry	Vandenberghe[7]	2018	With digitization, dental Imaging has advanced rapidly, including low-dose 3D computed tomography and optical techniques. The article aims to inform dental professionals about available digital tools for treatment follow-up.
Further opportunities for digital Imaging in dental epidemiology	Hogan et al.[13]	2018	Dental epidemiological research aids in monitoring the prevalence of oral diseases and organizing public health initiatives. The study looked at the increased diagnostic potential in image archives, offering insightful information while highlighting the need for clinical validation and considering alternative imaging modalities.
Digital Smile Design- An innovative tool in aesthetic dentistry	Jafri[14] et al.	2020	Digital smile design (DSD) is a useful tool in aesthetic dentistry. It enables patients to visualize and actively participate in smile design. This review examines DSD's use, benefits, drawbacks, and potential applications in aesthetic dental practice.
3D Digital Smile Design With a Mobile Phone and Intraoral Optical Scanner	Daher et al.[15]	2018	Extraoral facial scanning with smartphones is a reasonably priced alternative for use in patient education and 3D digital smile design. It is especially promising for general practitioners who might not have access to expensive digital impression equipment. This article describes a straightforward workflow that will benefit GPs from 3D facial scanning.
3D Printing and Digital Processing Techniques in Dentistry: A Review of Literature	Lin et al.[16]	2019	Rapid 3D printing technology development has created new opportunities in the medical field, including dentistry. To shed light on the significance and difficulties of 3D printing in dental applications, this review examines various 3D imaging technologies and recent developments in 3D digital processing techniques, emphasizing technology optimization and potential translational applications.
3D Printing in Dentistry—State of the Art	Kessler et al.[17]	2020	Due to its engineering benefits, three-dimensional (3D) printing is becoming increasingly common in dentistry. It offers a variety of materials, such as ceramics, metals, and plastics. The technology is considered crucial to the coming industrial revolution and has rapidly evolved due to patents that have run their course.
3D printing in dentistry – Exploring the New Horizons	Vasamsetty et al.[18]	2020	3D printing is revolutionizing healthcare by fusing science, engineering, and medicine. The development of patient-specific models, surgical guides, prostheses, and drug delivery devices provides accuracy and personalization in healthcare.
3D printing in dentistry	Prasad et al.[19]	2018	3D printing, also known as additive manufacturing, emerged in the 1980s but gained prominence in the 21st century. In dentistry, it is becoming increasingly important due to its customization capabilities.

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Continuation

Patient-reported outcome Measures (PROMs) of posterior single-implant crowns using digital workflows: A randomised controlled trial with a three-year follow-up.	Joda et al.[20]	2018	Patient-reported outcome measures (PROMs) for implant crowns made using entirely digital workflows and those combining analogue-digital techniques were compared in a randomized controlled trial (RCT)
The Crucial Role of Imaging in Digital Dentistry	Vandenberghe[21]	2020	The streamlined workflows of digital dentistry, powered by Imaging and 3D radiography, provide accuracy and efficiency, enabling in-office computerized treatments. It is important to implement digital processes.
Accuracy and practicality of intraoral scanner in dentistry: a literature review	Kihara et al.[22]	2020	The accuracy of intraoral scanners is expected to increase as they continue to develop. To guarantee their dependability in dental applications, their accuracy should be systematically verified.
Teledentistry during COVID-19 pandemic	Ghai[23]	2020	In the COVID-19 era, teledentistry, which uses information technology to enable remote dental treatment and consultation, can be a useful addition to conventional dental care. It allows dental practices to reopen with a lower risk of infection.
Artificial intelligence in dentistry: chances and challenges	Schwendicke et al.[24]	2020	Artificial Intelligence holds great promise in dentistry for streamlining procedures, cutting costs, and enabling personalized, predictive, preventive, and participatory dentistry.
Developments, application, and performance of artificial Intelligence in dentistry – A systematic review	Khanagar et al.[25]	2021	AI-based automated systems in dentistry exhibit excellent performance, sometimes matching or even exceeding the precision and accuracy of licensed dental specialists.
CAD-CAM Technology: A literature review	Abdulla et al.[26]	2020	Dental CAD/CAM technology involves creating various dental restorations by designing and milling two- or three-dimensional models with computer-controlled machines.
CAD/CAM ceramic restorative materials for natural teeth	Spitznagel et al.[27]	2018	Polymer-infiltrated ceramic network CAD/CAM blocks and full-contour zirconia restorations are becoming increasingly popular because they offer highly aesthetic, biocompatible, and durable options for dental restorations.
CAD/CAM produces dentures with improved fit	Steinmassl et al.[28]	2018	CAD/CAM technology produces dentures with superior fit compared to conventional dentures.
Digital Undergraduate Education in Dentistry: A Systematic Review	Zitzmann et al.[29]	2020	Digital methods, such as e-learning, simulators, digital radiography, and augmented/virtual reality, which can offer more engaging and natural learning experiences, have the potential to revolutionize dental education.
Digital learning resources for prosthodontic education: the perspectives of a long-term dental educator regarding 4 key factors	Goodacre[30]	2018	3D education programs can improve student education by fostering students' spatial awareness, interactivity, critical thinking, and comprehension of clinical correlations across dental disciplines.
Augmented and virtual reality in dental medicine: a systematic review	Joda et al.[31]	2019	Dental medicine is becoming more interested in augmented reality/virtual reality (AR/VR), particularly in education and training.

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Continuation			
A scoping review of the use and application of virtual reality in pre-clinical dental education	Towers et al.[32]	2019	In addition to challenging presumptions in previous literature, the study identifies emerging themes and summarizes current trends in virtual reality for dental education.
Dental students' performance in detecting in vitro occlusal carious lesions using ICDAS with e-learning and digital learning strategies	Alves et al.[33]	2018	Following training with ICDAS e-learning and ICDAS e-learning + digital learning tools, dental students' performance in identifying occlusal carious lesions significantly improved
Use of digital technology to improve objective and reliable assessment in dental student simulation laboratories	Miyazono et al.[34]	2019	In a dental student simulation lab, the PrepCheck tooth preparation assessment software program significantly increased intra- and inter-grader agreement compared to the conventional visual grading method.
Big data and digitalisation in dentistry: a systematic review of the ethical issues	Favaretto et al.[35]	2020	The study's key conclusions on ethical issues in digital dentistry include patient privacy, data security, informed consent, image tampering for scientific misconduct and insurance fraud, problems with online professionalism, and the influence of commercial interests via digital channels.

Digital Imaging and Diagnostics

Digital Imaging has undergone several significant technological advancements, with the digitization of X-ray diagnostics and the introduction of low-dose 3D computed tomography. New optical imaging techniques have also emerged for therapeutic dental Imaging[7]. This technology enables clinicians to plan and stimulate treatment digitally, use 3D-printed models for precise execution, and monitor treatment effectively[7]. By making it possible to track the distribution and prevalence of oral diseases precisely, digital Imaging has the potential to improve healthcare services. This data-driven strategy may result in more efficient dental healthcare service delivery, ultimately improving patient care and outcomes[13].

Before any physical treatment starts, a digital mockup of the proposed smile transformation is created and presented, allowing patients to visualize and actively participate in the design process. Additionally, DSD significantly increases case acceptance because it helps patients understand the proposed changes to their smiles, promoting their confidence and trust during dental treatment[14].

Recent research has demonstrated how well it reduces observer bias, particularly when using anonymized images to support remote scoring and examiner blinding. This method standardizes testing conditions while enabling concurrent evaluations by numerous examiners at various sites, reducing the time between examiner training and image evaluation[13]. These benefits help to improve the quality and integrity of oral healthcare research by enabling the collection of more precise and reliable epidemiological data[13].

3D Printing in Dentistry

The rapidly developing field of 3D printing has many uses in the medical and dental fields. This technology is especially useful in the dental industry because it allows for customizing and personalizing dental products[16]. 3D printing relies on intricate 3D CAD files, typically in stereolithography (STL) format, which triangulately describe object surfaces[17]. Three corner points and corresponding surface normals define triangular facets, and polyhedra are used to approximate curved surfaces. Multiplying the polyhedra improves surface resolution and decreases secant errors, resulting in higher-quality 3D products[17].

In dentistry, 3D-printed custom models are essential resources for diagnosis, enabling clear communication among surgeons about surgical techniques and assisting patients in understanding upcoming operations[18]. Based on the visual aids these models provide, patients can interact with the prosthesis or even help modify the treatment strategy. Three-dimensional printing (3DP) technology simplifies the creation of porous titanium implants, as it utilizes a high-power laser beam to fuse metal particles layer by layer on a powder bed, eliminating the need for post-processing steps[19]. Dentistry further benefits from 3DP in crafting crown copings, partial denture frameworks, surgical instruments, oral and maxillofacial implants, forensic odontology, and educational simulation models. This technology streamlines dental applications, enhancing precision and customisation[19].

Intraoral Scanners

A revolutionary development in dental practice, intraoral optical scanning (IOS) has digitized the patient's oral anatomy to enable chairside or lab-made restorations, comprehensive oral rehabilitation planning, and overlaying with 3D radiography, particularly for guided implant placement[20]. Studies highlight its advantages over conventional impression techniques, including time efficiency, strong patient and operator acceptance, improved precision, and reproducibility[7].

2D or 3D radiographic techniques are frequently used to obtain internal information, and non-ionizing fluorescence-based rays are increasingly used to assess internal structural integrity without harming the patient[21]. Digital impressions and image fusion algorithms have made it possible to develop computerised treatment planning and analysis tools due to the adoption of 3D CBCT imaging and low radiation doses[21,36].

Teledentistry

Through information technology, teledentistry replaces conventional face-to-face patient interactions by remotely providing dental care, advice, and education[23]. Teledentistry has proven useful in remote dental screening, diagnosis, consultation, and treatment plan proposals. It is particularly successful among schoolchildren, long-term healthcare facilities, and areas with limited access to dental facilities[37]. This method has eliminated geographical barriers and improved accessibility to dental care, making it an important tool in contemporary dentistry[23]. Notably, remote diagnoses of oral conditions like dental caries have shown high specificity and sensitivity,

demonstrating the efficacy of this method. In general, dentistry practices a 12-month teledentistry trial to evaluate its cost-effectiveness.

Artificial Intelligence in Dental Practice

Artificial Intelligence (AI) is the study of data patterns to make predictions[24]. Artificial Intelligence (AI) includes machines that perform human tasks. Artificial Intelligence (AI) is primarily used in virtual environments in dentistry. AI algorithms make possible risk factor prioritization, simulating and evaluating potential treatment outcomes, and differentiating between pathological conditions and normal anatomical structures[25]. These programs are especially useful for identifying oral diseases, planning treatments, and estimating the likelihood of success for various therapeutic modalities.

CAD-CAM Technology

"Computer-aided Design-Computer-Aided Manufacturing.", commonly known as CAD-CAM, is a Dental Technology. A wider variety of restorative materials has emerged in response to the rising demand for chairside CAD-CAM restorations, promising clinicians quick, accurate, and aesthetically pleasing outcomes in line with minimally invasive dentistry principles[38]. With the increasing adoption of chairside CAD-CAM technology by dental professionals and manufacturers expanding material options, the field is witnessing reduced chair time and heightened precision and aesthetics[26].

The digital workflow comprises three steps: Digital Impression using an intra-oral scanner, Data processing using digital software, and precise restoration production[26,38]. Computer-assisted dental restoration offers three modes of production: Chairside, laboratory, and centralized production. Chairside production occurs within dental surgery, offering convenience and direct fabrication of restorations[39]. Laboratory production follows the traditional dentist-laboratory workflow, except the impression is taken with an intra-oral scanner instead of the conventional impression technique.

The demand for aesthetically pleasing, biocompatible, and long-lasting restorations is satisfied by ongoing CAD-CAM ceramic restorative systems development. Ceramic network CAD-CAM blocks with polymer infiltration present novel chairside options with high edge stability for narrow margins[27]. Manufacturing for dependable, affordable, and adaptable teeth-supported restorations is streamlined by CAD/CAM[27]. Subtractive production is making things by removing material using tools and procedures like milling, grinding, or drilling.

Virtual Reality and Dental Education

With improved spatial abilities, interactivity, critical thinking, and a deeper understanding of clinical correlations across various dental disciplines, cutting-edge 3D education programs have transformed dental education[29]. Particularly for fixed or removable partial denture (RPD) programs, augmented reality in 3D visualization offers priceless insights into tooth morphology and significantly facilitates treatment planning[29]. Digital technologies have also made printing virtual teeth in three dimensions possible, giving all students access to a consistent and open learning environment[30]. These developments are revolutionizing dental education by encouraging a more thorough

and practical approach and preparing students for the complexity of contemporary dental practice[30].

Establishing cloud-based records and facilitating effective data storage, evaluation, and feedback processes are two benefits of digitization in dentistry[33]. It also enables the development and distribution of e-learning modules, improving accessibility and adaptability in dental education and practice. These digital tools revolutionize dental training and patient care by providing access to vital information and educational resources[33]. Digital software tools improve students' visualization abilities, offer immediate feedback, and significantly raise teacher and student evaluations[34,40]. Additionally, they enable students to recognize and fix mistakes, promoting a more thorough and efficient learning environment in dental education[34,40].

Discussion

By examining prior knowledge, new research, and emerging trends, this study highlights the potential benefits for patients, practitioners, and the entire dental industry. This review identifies significant challenges that must be overcome to integrate digitalisation into dental practice successfully.

Along with potential benefits for patients, practitioners, and the entire dental industry, it also highlights significant challenges that must be overcome to integrate digitalization successfully into a dental practice. Specifically covered in this article are significant subtopics like digital Imaging and diagnostics, 3D printing in dentistry, intraoral scanners, teledentistry, artificial Intelligence in dental practice, CAD-CAM technology, digital workflow, telehealth dentistry, virtual reality, and more. By addressing these areas, this review sheds light on the profound implications of digital innovations for the future of oral healthcare and emphasises the need for further research to bridge existing gaps.

Digital Dentistry has opened a new array of possibilities in Oral Health, as the field is evolving daily. This review identifies several key advancements and trends in digital dentistry, emphasizing their significant impact on clinical practice and education. Digital imaging and diagnostics have greatly enhanced the precision and efficiency of dental assessments, enabling more accurate detection and treatment planning[41]. 3D printing has revolutionized the customization and production of dental prosthetics, making it possible to create highly personalized dental restorations[7,13,17]. Intraoral scanners have improved the process of creating digital impressions, enhancing patient comfort and reducing procedural time[15,22]. Teledentistry has expanded access to dental care, particularly in remote and underserved areas, by facilitating remote consultations and treatment planning[23]. Artificial intelligence (AI) has shown great promise in improving diagnostic accuracy and personalizing treatment plans[3,6]. CAD-CAM technology has streamlined the production of dental restorations, while virtual reality (VR) has enriched dental education by providing immersive learning experiences[26,38,42]. Despite these advancements, challenges such as data security, ethical concerns, and the need for comprehensive training programs remain significant hurdles.

One of the primary strengths of this review is its comprehensive scope, covering a wide range of digital technologies and their applications in dentistry. By incorpo-

rating recent research, the review highlights the latest advancements and trends in digital dentistry, providing valuable insights for dental practitioners. Additionally, the discussion on the practical applications of these technologies in clinical settings enhances the practical relevance of the review. The findings align with previous research indicating that digital tools enhance dental diagnostics and treatment. For example, Vandenberghe[7] (2018) and Hogan et al.[13] (2018) emphasize the benefits of digital imaging in improving diagnostic accuracy and monitoring oral diseases. In a study, Chaudhuri et al.[43] (2020) confirmed the accuracy of 3D-printed digital models and established their applicability in clinical settings. A study by Kihara et al.[22] (2020) observed that illumination and colour temperature impact the accuracy of intraoral scanners. These scanners can produce partially edentulous fixed prostheses and have good repeatability, but they present difficulties for cross-arch fixed prostheses. Intraoral scanners were also the focus of a study by Mangano et al.[44] (2017), which highlighted their accuracy and efficiency. This review corroborates these findings and expands on them by discussing the impact of intraoral scanners on patient comfort and procedural time.

Similarly, Jafri et al.[14] (2020) and Daher et al.[15] (2018) highlight the positive impact of digital smile design on patient satisfaction and case acceptance. A study by Steinmassl et al.[28] (2018) supported better fit and improved retention of the dentures manufactured by CAD-CAM, owing to being subtractively manufactured, eliminating this issue. It also observed clinical benefits of enhanced retention and reduced traumatic ulcer frequency in CAD-CAM dentures. A recent review by Joda et al.[31] (2019) clarifies the expanding applications of augmented reality (AR) and virtual reality (VR) in dental care, particularly in the training of motor skills and the clinical evaluation of maxillofacial surgical protocols. Another recent scoping review on VR in pre-clinical dental education by Towers et al.[32] (2019) identified important thematic areas like simulation hardware, simulation realism, scoring systems, and validation. The review by Daher et al.[15] (2018) on virtual reality in dental education underscores its benefits for immersive learning experiences, which align with the findings of this review. This review, however, also considers the potential challenges in implementing VR technology in dental education. Estai et al.[37] (2018) explored teledentistry and discussed its potential to improve access to dental care. This review builds on their findings by examining the broader implications of teledentistry for addressing healthcare disparities and improving overall dental care accessibility.

Moreover, several challenges need to be addressed in the area of digital dentistry. Patient privacy, particularly in terms of anonymization and confidentiality, is the main ethical concern related to the growing digitalization of dentistry[45]. One of the primary concerns is safeguarding patient data in an increasingly digital environment, as maintaining data integrity during acquisition, transmission, and storage is crucial to prevent cyberattacks and data breaches. A comprehensive training program for dental staff is also necessary due to the adoption of advanced digital technologies[45]. Informed consent-related ethical concerns are pertinent in digital dentistry, necessitating specific consent for clinical trials, clinical care, and the use of secondary data in research. Discussions on consent and data security, particularly concerning Big Data applications, are crucial for ensuring ethical practices in both research and clinical care[35].

The integration of digital technologies in dentistry requires investment in training and infrastructure to maximize their benefits. Policymakers should support initiatives that promote the adoption of these technologies, particularly in underserved areas where teledentistry can significantly improve access to care. Future research should focus on the long-term outcomes of digital dentistry technologies and their cost-effectiveness. Investigating the ethical implications of AI and big data in dental practice is also crucial. Further studies should explore the interoperability of digital systems and the development of standardised protocols to enhance their integration into clinical practice.

In conclusion, digital dentistry, AI, teledentistry, and 3D printing have ushered in a new era of oral healthcare. These technologies offer numerous advantages, including improved diagnostics, treatment planning, patient communication, and education. However, challenges related to data security, accessibility, and cost must be addressed. The future of dentistry lies in continued innovation and ethical integration of these technologies to enhance patient care and outcomes. Dental education must adapt to equip the workforce with the necessary skills to navigate this digital landscape effectively. Ultimately, the convergence of technology and dentistry promises more efficient, accessible, and patient-centered oral healthcare.

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Declaration of Interest

The author(s) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The author(s) confirm that the data supporting the findings of this study are available within the article.

Competing Interest

The author(s) report that there are no competing interests to declare.

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Author Contribution

All author(s) actively participated in discussing the manuscript's findings and have revised and approved the final version of the manuscript.

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