

Review

The Transformative Impact of Digital Technologies on Modern Dentistry: A Narrative Review of the Applications and Benefits

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Abstract

Developments in technology, materials, and treatment methods have a strong impact on dentistry that has undergone a significant transition in recent years. The primary objective of this article is to comprehensively review the evolution of digital dentistry, focusing on the integration of cutting-edge technologies such as three-dimensional (3D) imaging, computer-aided design/computer-aided manufacture (CAD/CAM), intraoral scanners, and dental lasers, and their impact on enhancing the precision, efficiency, and patient-centered approach in modern dental practices. This study gathers and analyzes relevant research publications on the advancements in digital dentistry, with a particular emphasis on its applications in endodontics and restorative dentistry. The review process involved searching various academic databases, including PubMed, Embase, and Cochrane Library, for peer-reviewed articles published between 2010 and 2024. The selected articles were critically appraised, and the key findings were synthesized to provide a comprehensive understanding of the evolution and impact of digital technologies in contemporary dental care. The study revealed that integration of digital technologies has transformed the landscape of modern dentistry, leading to significant improvements in diagnostic accuracy, treatment planning, and patient outcomes. The adoption of 3D imaging, CAD/CAM, intraoral scanners, and dental lasers has revolutionized endodontic and restorative procedures, enhancing precision, efficiency, and patient satisfaction. Digital technologies have enabled more accurate identification of dental caries, periapical lesions, and complex root canal morphology, leading to better-informed treatment planning and more successful root canal therapy. Similarly, digital advancements in restorative dentistry have facilitated the fabrication of customized prosthetics, resulting in improved aesthetics, function, and long-term durability. The holistic, patient-centered approach enabled by digital dentistry has the potential to significantly improve overall oral health and quality of life for patients.

Keywords: *Digital dentistry, CAD/CAM, Intraoral scanners, three-dimensional (3D) imaging and intra-oral scanners*

Introduction

A broad variety of dental technology that uses computer-based parts, including hardware and software, is referred to as digital dentistry. The goal is to make it possible for dentists to treat patients using computer-assisted instruments. Dental professionals may now take impressions, conduct diagnostics, and plan treatments without the need for mechanical instruments according to new developments like digital scanning. Impression scanners and design software are examples of digital dentistry solutions for labs that greatly expedite the production of dental products and minimize manual work. The origins of digital dentistry are closely tied to advancements in technology. In 1984, nearly 40 years ago, French dentist Dr. Francois Duret introduced the use of computer-aided design and manufacturing (CAD/CAM) concepts for taking dental impressions (1). Since then, dentists from all over the world have developed and legally protected numerous computerized dental solutions to streamline the dental treatment procedure. However, it appears that dentists are taking their time adopting this digital technology. According to one online statistic, around 85% of dental clinics worldwide still take impressions using an impression tray (1). The use of digital technology into different elements of dental practice has resulted in a considerable revolution of the discipline in recent years. Digital dentistry comprises a diverse set of technology and procedures, including three-dimensional (3D) imaging, CAD/CAM, intra-oral scanners, and dental lasers (2). These advancements have not only increased the precision and accuracy of dental operations but also resulted in a more patient-centered approach to oral healthcare (3).

There are several uses for digital dental technologies that are accessible for dental labs or clinics. Although they were developed independently, imaging, scanning, digital design, and 3D printing or milling work in tandem to plan treatments, create designs, and produce finished products. Research by Pentapati and Siddiq demonstrates how digital dentistry procedures and scanning technology (such as intraoral or impression scanning and related

software) can enhance the strength and aesthetics of restorations while lowering expenses and increasing practice productivity (4).

This review article aims to examine the evolution of digital dentistry, with a focus on the integration of advanced technologies such as 3D imaging, CAD/CAM, intraoral scanners, and dental lasers. It also explores how digital dentistry improves precision and efficiency and promotes a patient-centered approach in modern dental practices.

Methodology

A comprehensive literature review was conducted by searching electronic databases, such as PubMed, Medline, Embase, and Google Scholar. The search utilized keywords such as “digital dentistry” or “three-dimensional (3D) imaging” or “computer-aided design and manufacture (CAD/CAM)” or “digital smile design” or “intra-oral scanners” to retrieve relevant articles pertaining to the standardization of aesthetic parameters. In total, 32 articles were carefully selected based on the following inclusion criteria: articles published between 2010 and 2024, studies specifically addressing parameters for digital dentistry, human studies, and articles written in English. These 32 articles were summarized to identify the parameters used to evaluate dental digitalization and facilitate a comparison of various digital dentistry programs. After applying the following inclusion criteria, 26 articles were selected: articles published between 2013 and 2023, clinical studies utilizing digital dentistry programs, human studies, and articles written in English. The Mendeley software was used to eliminate duplicate articles. Ultimately, 18 articles were included in the final review.

Review***Digital revolution******Digital Transformation of Oral Health Care***

Dentistry is one area of medicine that has profited from the advancement of current digital technology. The use of digitalization in dentistry is beneficial in modern dentistry, particularly given the numerous challenges posed by multiple chronic oral diseases,

the complex treatment required by the community with an aging population, and the continuous rising costs over one's lifetime (5, 6). Relevant industries and healthcare providers are exploring the implementation of digital computer-based applications facilitated by superfast broadband and the internet via smartphones, tablets, personal computers, and smartwatches to deliver comprehensive, yet simplified advanced management in dentistry (6, 7). Computer-generated treatment with centralized data gathering has been simplified in a variety of fields, including implant dentistry, restorative dentistry, oral and maxillofacial surgery (8, 9).

Digital Technologies in Endodontic Diagnosis and Restorative Planning

Endodontics and restorative dentistry play critical roles in protecting and restoring tooth health and functionality, therefore considerably improving overall oral health. Endodontics, a field of dentistry that focuses on the diagnosis and treatment of dental pulp and periapical tissues, can help save teeth that might otherwise be lost owing to permanent damage or infection (10). The fundamental goal of endodontic operations, like root canal therapy, is to eradicate infection, relieve pain, and preserve the tooth's structural integrity. The importance of endodontics is demonstrated by its capacity to cure disorders such as deep dental caries, trauma, and pulpitis, which, if left untreated, can lead to serious infections and jeopardize the vitality of the afflicted tooth (11). Endodontists can remove sick tissue from root canals, cleanse them, and then seal them to avoid re-infection. This allows patients to preserve their original dentition, reducing the need for extraction and promoting overall oral function (3). Restorative dentistry, on the other hand, supplements endodontics by concentrating on the restoration of damaged or missing teeth. Its relevance stems from the restoration of both form and function, allowing patients to bite, chew, and talk comfortably (12). Restorative procedures include a wide range of treatments, such as dental fillings, crowns, bridges, and implants. Dental diseases, fractures, and wear can all affect the structural integrity of teeth, therefore restorative

dentistry intervenes to restore and reinforce them (13). Endodontic treatment precedes restoration implantation, demonstrating the symbiotic link between the two. Following root canal treatment, teeth may be restored with crowns or other prosthetic devices to guarantee long-term function. This interdisciplinary approach stresses the holistic characteristic of dental treatment, addressing not just acute needs but also long-term patient outcomes (14). Endodontics and restorative dentistry have advanced dramatically in recent years, mainly in large part to the incorporation of cutting-edge digital technologies. The use of digital technology in endodontics and restorative dentistry has resulted in a significant shift in how dental practitioners diagnose, plan, and carry out treatments (15). This paradigm change is distinguished by enhanced accuracy, efficiency, and patient-centered care, which ultimately improves the overall quality of dental services (9). In endodontics, digital technology has transformed diagnostic imaging. This improves the accuracy of identifying dental caries, periapical lesions, and complex root canal morphology. Furthermore, the accuracy afforded by modern digital imaging techniques allows for more accurate treatment planning, which leads to better results in root canal therapy and surgical procedures (16). In addition, sophisticated endodontic software helps practitioners see internal tooth anatomy, navigate intricate root canal systems, and optimize treatment options (16). Augmented Reality and Virtual Reality are developing as training resources in restorative dentistry. These technologies provide immersive instruction and simulations of sophisticated restorative treatments in a virtual environment (17). Dental practitioners may improve their skills and experience in a risk-free environment, resulting in better patient results. The importance of digital technology in endodontics and restorative dentistry stems from its combined influence on enhancing diagnostic accuracy, treatment planning, and execution. These technologies foster a more patient-friendly experience, lower the invasiveness of operations, and add to the overall effectiveness and duration of dental interventions (17,18). As digital tools grow,

the dental environment is expected to see further breakthroughs, cementing technology's role in influencing the future of endodontics and restorative dentistry.

Digitalization of Pediatric Dentistry

Pediatric dentistry, which focuses on children's dental health from infancy to adolescence, necessitates a careful mix of modern treatment and a child-friendly approach. The introduction of digital technology has resulted in substantial changes in how dental treatment is delivered to this sensitive population. The goal of study of Schwendicke F was to investigate the digitalization trajectory in applied dentistry, evaluating its impact on clinical operations, patient outcomes, and educational opportunities (18). The landscape of pediatric dental treatment is changing as more dentists use novel digital technologies. Digital radiography reduces radiation exposure (Digital radiography requires 90% lesser dose compared to E-speed film) (19), which is especially important for younger patients, whereas intraoral scanners eliminate the need for conventional impressions, which can be uncomfortable for youngsters. The use of 3D printing technology not only speeds up the production of dental equipment but also provides interactive experience while explaining treatments to youngsters. Furthermore, teledentistry has emerged as a vital resource for delivering dental treatment to disadvantaged locations while assuring continuity of care through virtual consultations and remote diagnostic capabilities (20). The digitalization of pediatric dentistry includes not only clinical equipment but also instructional materials for both professionals and patients. Innovative software and programs create dynamic and engaging learning environments, assisting in the treatment of dental fear and instilling preventative oral practices at a young age (18,20).

Digital diagnosis

Digital Dentistry: Transforming Diagnostics and Treatment Planning

Significant advancements have been made in modern dentistry to improve patient comfort, improve diagnostic capabilities, and transform

treatment outcomes. Modern advancements have given dentists access to a greater range of instruments and methods, which has improved oral health, reduced invasiveness of treatment, and allowed for more accurate diagnosis. The use of digital technology in many facets of dental treatment is one of the biggest advancements in contemporary dentistry. Digital radiography, computer-aided design and manufacturing (CAD/CAM), and 3D imaging are among the methods used in digital dentistry. These developments have revolutionized treatment planning and diagnosis, giving dentists a more precise and effective way to care for patients (21). Traditional film-based X-rays have been replaced with digital sensors in digital radiography, which has reduced radiation exposure for patients and sped up image capture. Furthermore, improved image processing, zooming, and contrast modifications made possible by digital X-rays help dentists more precisely detect even the slightest tooth problems. With the use of CAD/CAM technology, dentists can now create dental restorations like veneers, crowns, and bridges in only one appointment, completely changing the area of restorative dentistry (22). Intraoral scanners make it possible to obtain digital impressions, doing away with the unpleasant traditional impression method. The restorations are then designed on a computer using these digital imprints, and the dental clinic uses high-quality materials to mill the restorations. This guarantees a precise fit and superior aesthetics in addition to saving time. Cone Beam Computed Tomography (CBCT), one of the 3D imaging modalities, offers a thorough and complete image of the patient's oral anatomy. When it comes to implant dentistry, CBCT scans are especially helpful because they let dentists evaluate the quantity and quality of bone, pinpoint anatomical landmarks, and carefully arrange implant placement (23). Patients benefit from improved results due to the success and predictability of implant therapies being greatly increased by this cutting-edge imaging technology (20, 24).

Digital dentistry: Is it constructive or destructive?

Our lives are full of digital systems. Since 2000, interconnectedness has grown by 1125%. As of June 2019, 57.3% of people worldwide had a cell phone, with ownership rising to above 80% in North America and Europe (9). Your voice is their command when using digital assistants to do tasks like ordering takeout, arranging for a car to drive you, translating spoken language into other languages, comparing goods brands, and much more (24). If you snore, beds can modify your posture automatically (25). Sensors in baby diapers track your child's activities to notify you when the diaper needs to be changed (26) Almost every device in your home, from window shades to pet feeders, can be controlled digitally with a push of a button or voice control (27). Therefore, it should come as no surprise that computerized systems are being used in dentistry more and more.

Despite all the advantages provided by modern technologies and digital dentistry, it is not without some disadvantages, the most important of which may be the lack of clinical sense. Dealing with digital dentistry also requires a type of special, sometimes intensive, training in order to obtain good results that lead to extreme mastery in the final product that serves the patient. A dentist who is not proficient in dealing with ExoCAD programs or similar programs will not be able to create a digital smile design or deal with a dental laboratory whose products are mostly specialized in this art. A dentist who has never dealt with CAD/CAM systems and has never taken training courses on how to properly use a scanner will undoubtedly not be able to obtain accurate results while using 3D printing (28). The rapid progress in technology, software, and machinery requires dentists to develop the skills needed to effectively use these advanced tools and systems.

Study strengths: This review article deals in a comprehensive way explaining how digital technology began to enter the world of dentistry, and one of the things that strengthens this narrative review is the recognition of how digital technology was introduced into the details of each of the different branches of dentistry. This review article is

distinguished by giving examples and applied models of the latest digital technologies through which various treatments are practiced on a daily basis in many dental clinics around the world, where thousands of patients are treated in various fields and branches of oral and dental medicine.

Study limitations: Although this narrative review sheds light on many therapeutic practices in digital dentistry, there remain points that have not been fully addressed. This includes, for example, various applications and uses of artificial intelligence in the fields of dentistry. There is also an aspect of the uses of virtual reality and augmented reality in refining the skills of dentists as an alternative to workshops that require providing the necessary means and tools for training, while the uses of virtual or augmented reality greatly facilitate the process of simulation, training, and refining the skills of doctors.

Future prospects: Dozens of questions are on the minds of many doctors and those interested in medical fields, including of course the field of dentistry, about what comes next. Will robots replace doctors? Will doctors turn into assistants to machines or even unemployed due to machines taking over jobs and job opportunities? Of course, things are not as bleak as that, but the rapid development in the use of digital dentistry, artificial intelligence, and virtual or augmented reality remains, which suggests the extent of the extreme development that the modern world is going through.

Conclusion

The integration of digital technologies has transformed the landscape of modern dentistry, leading to a significant improvement in diagnostic accuracy, treatment planning, and patient outcomes. The adoption of 3D imaging, CAD/CAM, intraoral scanners, and dental lasers has revolutionized endodontic and restorative procedures, enhancing precision, efficiency, and patient satisfaction. The swift advancement of machines, technologies, and software requires a parallel enhancement in dentists' skills to effectively utilize these modern tools and innovations.

Disclosures

Author contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Ethics statement

Not applicable.

Consent for publications

Not applicable.

Data availability

All data is provided within the manuscript.

Conflict of interest

The authors declare no competing interest.

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