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Impact of Digital Technologies on the Performance of Contemporary Dental Practice

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تأثير التقنيات الرقمية على أداء ممارسة طب الأسنان المعاصرة

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Abstract:

Dentistry has undergone a significant transformation thanks to digital technologies, including 3D imaging, CAD/CAM systems, and 3D printing. While these tools enhance accuracy, efficiency, and the patient experience, they also pose challenges, such as high costs and psychological stress for practitioners. Despite the benefits of digitalization, barriers to adoption include expensive equipment and software, ongoing training requirements, data security issues, and psychological pressures on dental teams. This study aimed to collect and analyze clinical trials on digital applications in prosthetic diagnostics and treatment planning by examining their clinical relevance and future potential. It reviews the current status, advantages, limitations, and obstacles of using digital technologies in dental practice. A comprehensive search was performed across multiple electronic databases, including PubMed, Google Scholar, Scopus, and Web of Science. Keywords included “Digital workflow,” “Dental Imaging,” “CAD-CAM,” “Digital Dentistry,” “3D Printing,” “Intraoral Scanner,” “Artificial Intelligence (AI),” “Teledentistry,” and “3D Dentistry.” Articles published from 2017 onward, focusing on peer-reviewed journals and reviews with detailed insights into digital dentistry, were selected. Accuracy is improved by intraoral scanners, which reduce errors by up to 30% compared to traditional impressions. CAD/CAM systems can achieve up to 95% accuracy in crown fabrication. Digital design ensures consistent results and better reproducibility. Seventy percent of dentists report needing extensive training. In conclusion, digital technologies have transformed dentistry by increasing accuracy and reproducibility. However, widespread adoption depends on overcoming financial barriers. Enhancing training programs and providing psychological support for dental teams are essential. Additionally, AI is expected to play a larger role in diagnosis, and more research is needed to evaluate its impact on reducing treatment times. Long-term cost-benefit analyses of digitalization are also important. Furthermore, developing user-friendly digital tools to reduce practitioner stress remains a key priority.

Keywords: Digital dentistry; CAD/CAM; Three-dimensional printing; Digital workflow.

الملخص:

شهد طب الأسنان تحولاً جذرياً بفضل التقنيات الرقمية، مثل التصوير ثلاثي الأبعاد، وأنظمة التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب (CAD/CAM)، والطباعة ثلاثية الأبعاد. تُحسّن هذه الأدوات الدقة والكفاءة وتجربة المريض، إلا أنها تُشكّل أيضاً تحدياتٍ كالتكاليف الباهظة والضغط النفسي على الممارسين. على الرغم من فوائد الرقمنة، إلا أن عوائق التطبيق تشمل التكلفة الباهظة للمعدات والبرمجيات، ومتطلبات التدريب المستمر، ومشكلات أمن البيانات، بالإضافة إلى الضغوط النفسية على فرق طب الأسنان. هدفت هذه الدراسة إلى تجميع وتقييم التجارب السريرية التي تستكشف التطبيقات الرقمية في تشخيصات تركيبات الأسنان وتخطيط العلاج، من خلال تقييم أهميتها السريرية وإمكاناتها المستقبلية. تناقش الدراسة الوضع الراهن، ومزايا، وقيود، وتحديات تطبيق التقنيات الرقمية في ممارسة طب الأسنان. أُجري بحث شامل في قواعد بيانات إلكترونية متنوعة، بما في ذلك PubMed، وGoogle Scholar، وScopus، وWeb of Science. تضمنت الكلمات الرئيسية المستخدمة "سير العمل الرقمي"، و"تصوير الأسنان"، و"التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب"، و"طب الأسنان الرقمي"، و"الطباعة ثلاثية الأبعاد"، و"الماسح الضوئي داخل الفم"، و"الذكاء الاصطناعي"، و"طب الأسنان عن بُعد"، و"طب الأسنان ثلاثي الأبعاد". تم اختيار المقالات المنشورة منذ عام 2017 فصاعدًا، مع التركيز على المجلات والمراجعات التي تمت مراجعتها من قِبل الأقران والتي تقدم رؤى متعمقة في طب الأسنان الرقمي. يتم تحسين الدقة من خلال الماسحات الضوئية داخل الفم، والتي تقلل الأخطاء بنسبة تصل إلى 30٪ مقارنة بالطبعات التقليدية. يمكن لأنظمة التصميم بمساعدة الحاسوب/التصنيع بمساعدة الحاسوب تحقيق دقة تصل إلى 95٪ في تصنيع التيجان. يضمن التصميم الرقمي نتائج متسقة ويعزز إمكانية إعادة الإنتاج. أفاد 70٪ من أطباء الأسنان أنهم بحاجة إلى تدريب مكثف. في الختام، أحدثت التقنيات الرقمية ثورة في طب الأسنان من خلال زيادة الدقة وإعادة الإنتاج. ومع ذلك، فإن اعتمادها على نطاق واسع يعتمد على التغلب على العوائق المالية. يعد تحسين برامج التدريب وتقديم الدعم النفسي لفرق طب الأسنان أمرًا بالغ الأهمية. بالإضافة إلى ذلك، من المتوقع أن يلعب الذكاء الاصطناعي دورًا أكبر في التشخيص، وهناك حاجة إلى مزيد من البحث لتقييم أثره في تقليل وقت العلاج. كما أن تحليلات التكلفة والفائدة طويلة المدى للرقمنة ضرورية. علاوة على ذلك، لا يزال تطوير أدوات رقمية سهلة الاستخدام لتخفيف ضغوط الممارسين الطبيين أولوية.

الكلمات المفتاحية: طب الأسنان الرقمي؛ التصميم بمساعدة الحاسوب؛ الطباعة ثلاثية الأبعاد؛ سير العمل الرقمي.

Introduction

Modern dental procedures are now far more accurate and reproducible because of digital technologies, which have totally changed the dental industry. Additionally, digitalization has expedited dental practices' workflows and enhanced the quality of patient treatment (Joda et al., 2024). Clinical results are improved by the more accurate and individualized treatments that dentists may provide, thanks to this technology. These technologies affect clinical practices, which have been highlighted by recent studies. Dental practice has been transformed by innovations like digital radiography and computer-aided design/computer-aided manufacture (CAD/CAM) systems (Alghauli et al., 2025; Bernauer et al., 2023). For example, it has been demonstrated that improvements in three-dimensional imaging, like Cone Beam Computed Tomography (CBCT), enhance treatment planning and lower surgical procedure faults (Meto & Halilaj, 2025). In comparison to conventional techniques, the advent of CAD/CAM technologies has also made it easier to produce dental restorations with higher dimensional precision (Abdulkarim et al., 2024; Bernauer et al., 2023).

Digitalization promotes communication between dental labs and clinics through digital file sharing, saves time, and lowers errors by replacing manual labor and traditional impression materials. Additionally, it reduces manual labor by using automated systems for follow-ups, billing, and scheduling. Decision-making procedures can further be streamlined by artificial intelligence (AI) solutions. To maximize the usefulness of digital tools, ongoing evaluation is essential (Bernburg et al., 2025; Gebhardt et al., 2025). Nevertheless, there are drawbacks to implementing these technologies, such as the expense of hardware and software, reliance on technology, and cybersecurity threats (Alqahtani, 2024). Although these instruments enhance precision, effectiveness, and patient satisfaction, they also present drawbacks, including exorbitant expenses, the need for continual training, and mental strain on professionals. Therefore, this study aims to analyze the impact of digital technologies on accuracy in diagnosis and treatment, reproducibility of procedures, and to provide a framework for integrating digital tools with clinical practices. It discusses the current state, benefits, limitations, and ethical considerations of applying digital technologies to dentistry.

Materials and Methods

Several electronic databases, including PubMed, Google Scholar, Scopus, and Web of Science, were thoroughly searched. "Digital workflow," "Dental Imaging," "CAD-CAM," "Digital Dentistry," "3D Printing," "Intraoral Scanner," "Artificial Intelligence (AI)," "Teledentistry," and "3D Dentistry" were among the keywords. Peer-reviewed publications and reviews offering in-depth information on digital dentistry were the main emphasis of the articles chosen, which were published starting in 2017.

Additionally, to locate more papers, a reference list of earlier reviews was examined. Every article that suggested a potential match or that was ineligible based on the title's information was taken into account and assessed. Only English-language publications were examined. The final selection comprised 44 papers in total. There was no more manual search done.

Artificial Intelligence (AI) in Dentistry

Artificial intelligence (AI) has gained popularity as a tool for dentistry diagnosis and treatment planning. By using AI systems as supplemental tools, dentists can improve diagnostic, treatment planning, and result prediction accuracy by using more accurate picture analysis (Alqahtani, 2024). AI tools work especially well for repeated jobs that require a lot of data. AI performs more accurately when the workload is greater (Joda et al., 2020). AI can be used to help dentists improve the caliber and precision of their work because dentistry includes a number of fields where automation and support might be advantageous. (Gao et al., 2025). General dentists can receive diagnostic assistance from deep learning technologies. For instance, by using tooth recognition and numbering to automatically complete computerized dental records, automated solutions can speed up clinical procedures and boost dental output. The accuracy of diagnosis can be further increased by using these devices for secondary views (Khanagar et al., 2021).

The most talked-about recent invention is personalized orthodontic care powered by AI. Orthodontic diagnosis, planning, and treatment monitoring are now all possible using AI (Gao et al., 2025). It has been found that AI algorithms can significantly improve diagnostic accuracy, leading to earlier detection of dental issues and better treatment outcomes (Maguluri, 2025; Tyagi et al., 2025). In line with this, a study by Volovic et al. (2023) explored how machine learning models can predict treatment success in orthodontics, showing promising results in enhancing the predictability of clinical outcomes. Digital models are increasingly used in orthodontics, allowing for greater reproducibility in treatment results (Meto & Halilaj, 2025). Additionally, digital tracking tools and augmented reality applications are starting to play a role in surgical procedures, helping dental professionals achieve precise results in complex interventions (Lin et al., 2024).

AI is being used to optimize material properties and predict their performance under various conditions. Machine learning models can analyze large datasets to identify biomaterials with enhanced durability, biocompatibility, and aesthetic qualities, paving the way for next-generation restorative materials. In prosthodontics, AI enhances the design and fabrication of dental prostheses through advanced CAD/CAM systems (Najeeb & Islam, 2025). A design assistant called RaPid for use in prosthodontics combines various aspects such as anthropological calculations, face dimensions, ethnicity, and patient preferences to offer patients the most suitable aesthetic prosthesis. RaPid connects databases, knowledge-based systems, and computer-aided design through a logic-based framework (Agrawal & Nikhade, 2022). With advancements in neural networks, labs are using AI to autonomously develop innovative dental restorations that meet the highest standards for fit, function, and aesthetics. This will benefit dentistry and also significantly impact orofacial and craniofacial prosthetics (Chander et al., 2024). However, in prosthodontics, AI technology remains limited due to the complex diagnostics and treatment protocols required for each individual (Bernauer et al., 2021).

Dental Digital Technologies

Digital technologies in dentistry encompass advanced tools such as CAD/CAM systems, digital radiography, intraoral scanners (IOS), and electronic health records (Schnitzler & Bohnet-Joschko, 2025). These technologies have emerged as a transformative force, offering substantial advances in both accuracy and reproducibility of clinical procedures. The studies reviewed provide compelling evidence of these advancements across various aspects of dental practice. These innovations enable:

- Precise digital impressions of teeth and surrounding tissues.
- Customized restorations (e.g., crowns, bridges, dentures) with high accuracy.
- Efficient communication between dental labs and clinics.

Their significance is seen in enhancing patient happiness, decreasing manual errors, and boosting procedural accuracy. Despite these advantages, dental professionals' use of digital technologies varies greatly and is impacted by a number of factors, including their level of technological readiness (Radwan et al., 2023). Facilitating a seamless transition to digital dentistry requires an understanding of these discrepancies. Evaluating these characteristics can help guarantee that all clinics, regardless of size or location, can benefit from technological improvements, since technology readiness affects how clinicians view and incorporate new technologies (Blut & Wang, 2019; Hammerton et al., 2022).

Digital Imaging

For diagnostic and treatment planning, radiographs and photos captured by cameras and iOS devices can be analyzed. In addition to eliminating the need for numerous laboratory tests and patient impressions, the results are frequently significantly more accurate than human perception (Agrawal & Nikhade, 2022). By helping radiologists diagnose illnesses, spot anomalies, and provide individualized treatment plans, AI-powered image processing is transforming medical imaging (Ali et al., 2025). Compared to traditional techniques, digital imaging—including IOS and digital radiography—improves diagnostic accuracy and lowers mistakes by 30% (Khalifa & Albadawy, 2024; Zakaria et al., 2025). These techniques enhance lab-clinic communication and make 3D modeling easier for treatment planning. The aligners can be easily 3D printed in accordance with a special treatment plan using precise 3D scans and virtual models. An algorithm that automatically identifies the ideal pressure, the best way to move patient teeth, and the pressure sites unique to each tooth or group of teeth is created as massive amounts of data are processed.

Intraoral scanners eliminate the discomfort involved with conventional impression techniques by making it easier to take digital images. After designing restorations on a computer using these digital imprints, the dental office mills the restorations using premium materials. In addition to saving time, this method guarantees a precise fit and enhanced aesthetics. One 3D imaging method that provides a thorough picture of the patient's oral anatomy is Cone Beam Computed Tomography (CBCT). CBCT scans are particularly useful in implant dentistry because they allow dentists to assess the amount and quality of bone, locate anatomical landmarks, and meticulously arrange implant placement (Meto & Halilaj, 2025). The importance of CBCT in improving surgical precision is highlighted by Gharat et al. (2025) who show a notable decrease in mistakes and better treatment planning. These results are corroborated by Baccher et al. (2024) who show that CBCT not only enhances vision but also reduces problems by offering a better grasp of anatomy. It is anticipated that aligners with artificial intelligence will reduce treatment duration, expedite appointment scheduling, guarantee accurate treatment execution, and track patient progress.

CAD/CAM Systems

CAD/CAM technologies have revolutionized the process for producing dental restorations in addition to imaging. According to AlRasheedi and Ibrahem (2025), CAD/CAM systems outperform conventional techniques in terms of dimensional accuracy and fit, which leads to improved results and increased patient satisfaction. Furthermore, a study by Hensel et al. (2021) provides information about the long-term benefits of restorations made using CAD/CAM, highlighting their accuracy and durability in comparison to their manually made equivalents. Restorative dentistry has fundamentally changed as a result of dentists using CAD/CAM technology to create restorations, including veneers, crowns, and bridges, in a single visit (Elmarakeby et al., 2025). Fixed dental prostheses often achieve a better marginal and internal fit when they are completely digitally manufactured with CAD/CAM technology, eliminating the need for a gypsum cast (Abdulkarim et al., 2024). According to Bernauer et al. (2023), CAD/CAM technology eliminates manual errors, allowing for 95% accuracy in the design and fabrication of dental restorations. Additional positive outcomes, such as shorter turnaround times and solutions tailored to each patient's needs, have also been observed.

Three-dimensional (3D) Printing

In manufacturing, the term "three-dimensional" (3D) printing is typically used to refer to a process that creates objects by layering them together. Rapid prototyping (RP) is another name for this technology, which is more accurately defined as additive manufacturing [3]. The American Society of Testing and Materials (ASTM) developed the additive manufacturing data format, which is used in additive manufacturing to create any 3D object that can be printed using a 3D printer. AMF provides compositions for color, materials, and texture (Rathee et al., 2021).

In this discipline, 3D printing is essential because it makes it possible to create highly tailored prostheses that restore both function and appearance. By creating prostheses that are customized for each patient's unique anatomy, this technology has completely changed the way that treatments are administered (Beefathimathul, 2025). Modern prosthodontics makes use of cutting-edge methods that provide accuracy and precision for specific rehabilitation treatments while also saving time. Digitalization, which includes 3D printing, is one such technology that closely satisfies the needs of contemporary prosthodontics. The manufacturing of a specific prosthesis is also influenced by the technician's and dentist's abilities. RP eliminates the need for part-specific tools and full human interaction in prosthesis manufacture. Better, quicker restorations are accomplished with less labor expense because there is no total human involvement. RP technology is a possible substitute for traditional dental prosthesis manufacture, given its benefits over traditional techniques (Rathee et al., 2022). A study by Kaushik et al. (2023) compared and assessed the impact of temporary restorations made using two methods—conventional and 3D printing—on the hard and soft tissues around early non-functional loaded implants in the mandibular posterior region. Based on an early nonfunctionally loaded implant in the mandibular posterior area, they concluded that the effects of traditionally fabricated and 3D printed provisional restorations on the hard and soft tissues surrounding the implant were similar.

Prosthodontic applications of 3D printing technology

Numerous in vitro and clinical studies have come to the conclusion that 3D printing technology is useful for treatment planning and has given prosthetic makers an alternative to the traditional way. Wax, metal, and resin are among the materials utilized. Zirconia is still in the experimental phase. Wax patterns, temporary crowns, all-ceramic crowns, and prosthesis casts are all made via 3D printing.

2.1. Wax pattern fabrication

Wax-up building can be done automatically with the use of RP technology. There are three steps involved: First, the master model is scanned; second, the wax pattern is created using specialized design software; and third, the wax-up is fabricated using fused deposition modeling (FDM). It features a high rate of manufacturing, minimal spruing time, good control over the thickness of the wax coping, and a shorter time required for metal coping trimming and finishing.

2.2. Direct dental metal prosthesis fabrication

3D printing speeds up the process of fabricating high-precision metal parts, whereas conventional fabrication takes longer. For this lab process, selective laser melting (SLM) and sintering are appropriate. The intricate shape can be customized using this method without requiring numerous manual pre- and post-processing processes. This method expedites the turnaround time for metal prosthesis fabrication and streamlines the traditional procedure.

2.3. Removable partial denture frameworks

Using the SLM process, Co-Cr alloy is used to fabricate frames for removable partial dentures. In their research on the construction of a framework using the SLM technique, the framework's object correctness and fit quality were equivalent (M. Rathee et al., 2022).

2.4. All-ceramic restoration fabrication

Green zirconia and all-ceramic dental restorations are made using a direct inkjet approach based on the slurry micro-extrusion principle. Although this technology offers excellent precision, minimal material intake, and cost efficiency, further research is still needed before it can be applied in clinical settings (Quadri et al., 2017).

2.5. Mold for complete dentures

For parametric placement of artificial teeth in complete denture manufacture, 3D records are obtained by scanning the rims and edentulous models in a centric relation. Physical flasks (models) are created using this data (Quadri et al., 2017). The application of 3D printing technology to complete dentures is not well-documented.

Digital workflow

Dental clinics have improved thanks to digital workflows. Complete digital workflows for single-visit treatments of monolithic fixed dental prostheses that are implant-supported and tooth-borne (tooth-supported) are made possible by the use of digital technologies. The design and manufacture of dental splints and fixed dental prostheses are progressively using the computerized workflow, which is already widely employed in dental surgery, particularly in implantology. The use of digital workflow for single crowns and fixed partial dentures with up to six pieces is now widely accepted (Kurbad, 2019; Moustapha et al., 2019; Onbasi et al., 2022).

Complete digital protocols consist of three main steps: (i) the 3D acquisition of the individual patient's situation directly in the mouth with IOS; (ii) digital design using dental software applications (CAD) for RP such as milling or 3D printing (CAM) in a fully virtual environment without any physical dental models (plaster casts); and (iii) clinical delivery of the dental restoration (Bernauer et al., 2023). There are many indirect methods for comparing conventional and digital workflows, including examining restoration fit after each technique (Abdulkarim et al., 2024; Kurbad, 2019; Onbasi et al., 2022). Best-fit alignment is the most common direct method for assessing the accuracy of different impressions (Onbasi et al., 2022). Park et al. (2020) discuss the use of digital models for treatment planning, which enables higher reproducibility in orthodontic results. Supporting this, a meta-analysis by Alharkan (2024) concludes that digital planning significantly improves treatment efficiency by reducing chair time and increasing patient compliance. For digital processing, a team-based approach is especially important—this includes the clinician, dental assistants, and technician (Bernauer et al., 2023).

Future Perspectives

Digital dentistry has the potential to greatly advance dental practice in the future. The integration of virtual reality (VR) and augmented reality (AR) into surgical education has demonstrated impressive potential. According to Lin et al. (2024) AR and VR are quickly transforming clinical practice and dental surgery education. In addition to changing how dentistry students are taught, these technologies are improving the caliber and effectiveness of clinical procedures. Dental practitioners will be better prepared to handle clinical issues as they advance and become more widely accepted, which will ultimately result in improved patient care and professional skill. Studies show that integrating AR and VR into normal dental operations is anticipated to become the norm for clinical training, patient education, and surgical planning. More extensive AR and VR technologies will boost surgical accuracy, encourage experiential learning in the classroom, and enhance patient-clinician communication. AR could increase the accuracy of many dental treatments, while VR simulations can boost the confidence and abilities of both dental professionals and students. To increase the accuracy of their treatments, clinicians are encouraged to employ AR-based technologies (Meto & Halilaj, 2025; Puleio et al., 2024).

Challenges

Even with these encouraging developments, there are still issues that need to be resolved when digital technologies are adopted. Investments in training and integrating these technologies are substantial. Approximately 70% of dentists require more education (Gebhardt et al., 2025). Additionally, when using digital platforms, practitioners need to be on the lookout for patient privacy and data security (Abdel-Jawad, 2024). As long as practitioners experience psychological strain from the quick changes in technology, digital stress should also be taken into account. Preliminary data about the digital stress experience in dentistry and pertinent associations were given in a prior study. Support and preventative actions are necessary in the context of continuous digitalization to lessen stress connected to technology (Bernburg et al., 2025). Financial barriers, including high equipment and software costs, also need to be tackled.

Conclusion

In conclusion, even though digital technologies greatly enhance the efficiency of dental treatments, removing obstacles to their use requires constant research and teaching. As the discipline develops further, cooperation between practitioners, educators, and researchers will be essential to making the most of these advancements for improved patient care. The industry must embrace upcoming innovations like artificial intelligence (AI) while addressing psychological, training, and financial issues. Future studies should concentrate on analyzing how AI might shorten treatment durations and determining how cost-effective digital technologies are over the long run.

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