JOURNAL OF WOMEN MEDICAL & DENTAL COLLEGE

Revolutionizing Prosthodontics with Artificial Intelligence

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Received date: 23-09-2023 **Publication date:** 10-09-2024

Abstract

The revolutionary impact of artificial intelligence (Al) on prosthodontics is addressed in this narrative review with focus on how it has changed the way patients are examined. Additionally, machine learning is used which aids in greater accuracy and customization when creating a treatment plan for the patient. Artificial intelligence (AI)-driven technologies are essential in the creation and manufacturing of prostheses and has improved computer-aided design (CAD) systems, making it easier to create customized, anatomically accurate prosthetic limbs. Apart from its practical uses Artificial Intelligence fosters an Ongoing investigation and advancement in the field of prosthodontics, as new materials, techniques, and treatment approaches are developed, Al system continuously incorporate lessons from real patient experiences, pushing the boundaries of what is possible in the field. To address the inherent difficulties in traditional approaches this paper explores a convincing case for using Al in decision making and treatment planning in prosthodontics. Through use of unique patient data to support evidence-based decisions treatment planning can become more precise and personalized by leveraging Al analytical powers. Furthermore, the incorporation of Al-powered technologies including CAD and 3D printing is being investigated as a way to optimize manufacturing process of different of prostheses. Al is playing a crucial role in molding the future of the discipline as highlighted by the ongoing research element. This article highlights the revolutionary potential of artificial intelligence (Al) in prosthodontics, providing a state of and patient-centered approach to dental care.

Keywords Artificial Intelligence, machine learning, prosthodontics, digital prosthodontics.

1. Introduction

The field of artificial intelligence (AI) encompasses scientific and engineering disciplines that are focused on developing computer programs and machines that possess intelligence (1, 2). Significant advancements in the last ten years such as artificial intelligence and machine learning have emerged as indispensable instruments in various healthcare delivery system areas (3). The goal of artificial intelligence is to develop intelligent computer programs and system that can carry out operations that have historically required human intelligence thus imitating the process of solving problems. Dentistry presents numerous prospects for incorporating robotic automation, artificial intelligence, and assistive technology to elevate the standards of dental care.4 Artificial intelligence plays a pivotal role in dentistry, particularly within the field of prosthodontics. Prosthodontics, which includes the study of dental prostheses, holds significant importance as it exerts a wide-ranging impact on various aspects of dental practice, which focuses on restoring and reconstructing missing teeth and associated structures through the use of implants for both permanent and removable prosthetic solutions (5, 6).

2. Digitalization in prosthodontics

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https://doi.org/10.56600/jwmdc.v2i3.77

The term "digitization" involves transforming an image or signal into AI code through scanning using a graphic tablet (indirect technique) or utilizing an analog (direct technique) to an AI conversion device (7). (Figure 1).

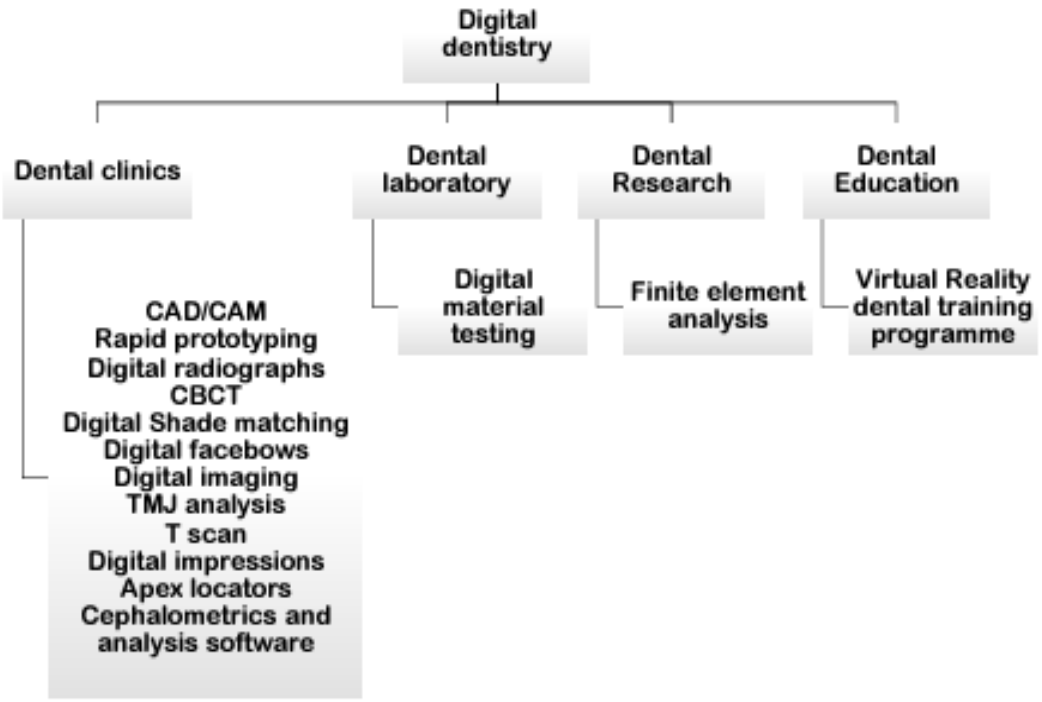

Figure 1: Aspects of digital dentistry (8).

2.1 Role of Digitalization

2.1.1 Patient education

Patients' understanding of oral health is facilitated through educational tools such as intraoral cameras and software (XCPT, Dentrix, Bite FX) featuring 2D/3D dental procedure images. These aids digitize analog or capture digital radiographs, allows clinicians to annotate and explain treatments with elements like crowns and implants (9). Acting as immediate consultation tools, they build trust, save time, and motivate patients with 3D treatment visuals (10).

2.1.2 Diagnosis

Digital radiography offers immediate image viewing, eliminating the need for dark rooms and chemicals. Radiovisiography (RVG) reduces radiation exposure compared to conventional radiography and benefits from advancements in intraoral camera technology. Advanced imaging options, like cone-beam CT and MRI, enhance TMJ understanding (7). Various imaging modalities, including digital panoramic imaging, aid in implant treatment planning, while digital photography, supports patient education and aesthetic treatment planning. Digital photographs find applications in maxillofacial restoration and medico legal documentation (11).

2.1.3 Treatment planning

Digital impressions, a revolutionary development in prosthodontics during the COVID-19 pandemic, has the potential to replace traditional materials, and can overcome their inaccuracies (12). It enables multiple uses without the need for disinfection, and is advantageous for patients with a hypersensitive palate. This technology has significantly shortened chair side time for CAD-CAM restorations (7).

2.1.4 Shade/color replication

Digital applications address the challenge of shade/color replication, reducing inter- and intra-operator variability. Visual shade matching is replaced by photography, colorimeters, and spectrophotometers (e.g., shade match, shade vision, shade eye, and clear match), providing a near-life effect with color mapping of teeth (8).

2.1.5 Occlusion and virtual articulators

AI can create the crown's occlusal shape based on opposing teeth, even amid wear or fractures, ensuring an

exact fit and ideal function. Similarly, AI aids in pre-programming teeth alignment for dentures, ensuring their proper functionality (10).

A crucial technological application is the use of virtual articulators for treating occlusion and restoring oral health. These articulators aim to closely simulate the oral environment, surpassing the limitations of mechanical counterparts. Designed for comprehensive static and dynamic occlusion analysis, virtual articulators intend to eliminate errors associated with mechanical models. Unlike their mechanical counterparts, virtual articulators can simulate specific masticatory movements, calculating contact points during mandibular animation. By considering muscle patterns, soft tissue resilience, and joint discs, virtual articulators strive to reproduce more realistic dynamic conditions of occlusion than traditional mechanical articulators (7).

2.1.6 Diagnosing and treating the occlusal errors

Analyzing occlusal problems is challenging due to the complexity of the human occlusal system. The T-scan system uses an automated computerized sensor for occlusion analysis, providing qualitative and quantitative assessments. It allows dynamic viewing of occlusion, timed force analysis, and permanent documentation of occlusal conditions (7) Mandibular kinematics, jaw tracking devices, and surface electromyography (EMG) devices like BITE STRIP™ aid in studying jaw movements, detecting irregularities, and assessing muscle activity related to malocclusion-directed nociception. Computerized pantographs contribute to accurate restoration of deteriorated dentitions and precise analysis of the stomatognathic system (11).

2.1.7 Removable and Fixed prosthesis

The integration of AI-driven progressions in the realm of prosthodontics has facilitated the use of digital impression-taking techniques and intraoral scanning methods, ensuring precise fabrication of fixed and removable prostheses (13). The utilization of a 3D face tracking system has emerged as an option that helps in crafting dental prostheses, offering a potential alternative to traditional methodologies (3).

2.1.8 Implantology

Implants present the benefit of increased resistance to dental issues, maintaining the remaining ridge and providing additional support for distal extensions (4). AI's incorporation into implantology holds the potential to unite these fields, laying the groundwork for forthcoming advancements in prosthetics (14, 15).

AI helps in forecasting implant stability and success rates. Through analyzing patient-specific data including bone density, implant dimensions and other factors. This assists clinicians in making better informed decisions during implant procedures planning and offers patients more precise insights into the potential outcomes of their treatment (15, 16).

2.1.9 Maxillofacial Prosthodontics

AI is making significant strides in maxillofacial prosthodontics, using convolutional neural networks (CNN) to create prosthetic devices that aid individuals with facial anomalies. These AI-driven devices, such as prosthetic eyes and intelligent reading glasses with voice-activated technology, help restore functionality and appearance, offering vision correction and assisting those with visual impairments in reading and recognizing faces (6).

Digital technology allows for the digital preparation of external implants and the design of maxillofacial prostheses. CAD/CAM technology starts with imaging (MRI and CT scans), capturing both hard and soft structures. This data is translated into an RP model, which can be printed in wax or resin and turned into a wax mold. Silicone elastomer prostheses are made after fitting on the cast. For facial alterations, CAD/CAM provides a faster alternative, creating maxillofacial prosthetics from a digital library (16, 17, 18, 19).

Tissue-engineered skin grafts promote oxygen supply, wound protection, faster healing, and infection prevention. In artificial olfaction, replicating the human olfactory system has intrigued scientists. The electronic nose model, imitating human olfaction with electronic sensors, represents a significant advancement in this field (20).

3. Computer- Aided Designing and Computer-Assisted Manufacturing (CAD-CAM)

Additive manufacturing, subtractive manufacturing, 3D printing are commonly used CAD-CAM technology for fabrication of prostheses in Prosthodontics (6).

3.1. CAD-CAM system has 3 components

1. Digital impressions/scanners: Intraoral scanners are useful in catering the problems related to impression

materials. Advantages of digital impressions include improved patient comfort by eliminating traditional impressions, minimized errors, streamlined lab procedures, quick review and modification of preparations, and instant data transfer to dental labs (6).

2. Designing final prosthesis: Upon receiving the scanned impression of the prepared tooth, the laboratory processes the data using design software. The software enables the creation of a precise three-dimensional image resembling the provisional restoration. Once the final prosthesis is designed, the data is transferred to a milling device (6).

3. Milling phase It entails sending finalized designs to a central milling or production center, where appropriate restorative material is milled using additive, subtractive, or 3D printing methods. This phase offers advantages including the elimination of materials like die and investment materials, time savings by bypassing casting procedures, minimized human errors, and efficient creation of precise final restorations (6, 19).

3.2. Aesthetic dentistry

Digital tools have revolutionized smile design, using precise software for meticulous planning. This leads to more predictable and visually appealing results for patients. Virtual smile design software allows customization of tooth contours, dimensions, shade, and arrangement, creating a unique smile that harmonizes with facial features and individuality (20, 21)

3.3. Limitations of AI

The integration of AI in prosthodontics raises ethical concerns around patient privacy and confidentiality. Job displacement for dental technicians is also a worry. Establishing ethical guidelines and regulations is vital for responsible AI application (22).

While there are drawbacks to using AI in dentistry, like system complexity, the need for proper training, and costly setup, there are issues like data snooping bias arising from using data for both training and testing. Additionally, the practical application of AI findings in dentistry isn't immediate (23, 24)

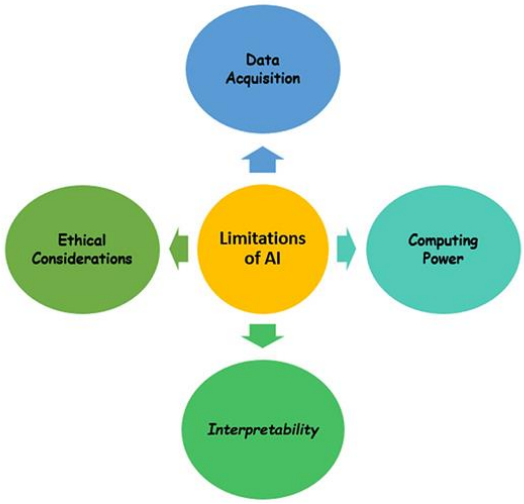

Figure 2: Limitations of AI (14)

AI in dentistry has some problems like complex systems, needing lots of training, and being expensive to set up. Using the same data for both learning and testing can make AI biased (25, 26). Nevertheless, future developments and research on AI can be eagerly awaited. (27, 28).

3.4. AI & Ethics:

It's crucial to consider the risks and challenges of AI in healthcare. Besides ethical issues, concerns about data protection and patient privacy persist. There's also the risk that AI might worsen existing healthcare inequalities and biases if not properly designed and implemented.29 Developing AI responsibly and ethically in healthcare requires careful attention to these concerns. Continuous oversight and assessment of AI systems are vital to avoid any negative effects (30, 31).

4. Conclusion

Overall, AI's potential in dentistry seems promising. It can improve diagnostic accuracy, assist in treatments, and refine prosthetic creation, transforming dentistry. However, ethical issues like data privacy and fair algorithms need addressing. Dental professionals should understand AI basics for responsible use. As AI services grow in dentistry, staying updated on advancements is crucial for choosing suitable services and improving the patient experience (32). Other areas to be explored include the use of virtual articulators and digital face

bows to facilitate the automatic design of the occlusal surface (33).

Conflict of interest The authors declared that they have no competing or conflict of interest.

Acknowledgements We are very grateful to all the participants who willingly participated in the study and contributed to the editorial

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