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Artificial Intelligence in Prosthodontics: Current Status and Future Prospective

[1]Dr. Rajat Lanzara

Corresponding Author: Dr. Rajat Lanzara

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Abstract

Artificial Intelligence (AI) has influenced all fields in Dentistry and Prosthodontics is no other exception. AI platforms in the form of Natural Language Processing and machine learning models are utilized to analyze and manage large volume of data, reducing manual input and errors. Currently AI is utilized in multiple applications in prosthodontics ranging from diagnosis, treatment planning, treatment and also post-operative care and management of patients. This article highlights the currently used AI platforms used in diagnosis, oral scans and digital workflows in fabrication of removable, fixed and implant supported prosthesis.

Keywords: AI Technologies, Deep Learning, Dental Prostheses, Enhanced Patient Satisfaction

Introduction

Artificial Intelligence (AI) has become a transforming force across multiple sectors of healthcare [1]. Within dentistry, AI's capabilities have been harnessed to enhance diagnostics, treatment planning, and patient management, revolutionizing how dental care is delivered. Specifically, in the field of prosthodontics, which deals with the restoration and replacement of lost or damaged teeth, AI technologies have emerged as a game-changer. Prosthodontists rely on precision and accuracy in the design and fabrication of dental prostheses, such as crowns, bridges, and dentures, to achieve optimal functional and aesthetic outcomes.

AI encompasses various technologies such as machine learning (ML), deep learning (DL), neural networks, and natural language processing (NLP), each with the ability to analyze large datasets, recognize patterns, and make predictions [2]. These technologies have been applied to key aspects of prosthodontic care, including diagnosis, digital imaging, virtual treatment simulations, and the fabrication of prosthetic devices. The introduction of AI into prosthodontics is not merely about automating manual processes; it fundamentally changes the paradigm of how prosthodontic care is approached. It allows for a more personalized treatment plan by analyzing individual patient data, offering tailored solutions based on the unique anatomical and physiological characteristics of each patient. This has led to better clinical outcomes, enhanced patient satisfaction, and a reduction in chairside time [3].

However, the integration of AI in prosthodontics is not without its challenges. Issues such as data security, the need for large training datasets, and resistance to technological adoption pose significant hurdles. Despite these challenges, the potential benefits and applications of AI in prosthodontics continue to expand, making it a rapidly growing field of interest. This article delves into the current status of AI in prosthodontics, examining how AI is being applied today, its advantages, and the obstacles that must be overcome. Additionally, it explores the future prospects of AI in this field, looking at how emerging technologies may shape the future of prosthodontic care.

Current Status of AI in Prosthodontics

he current status of AI in prosthodontics reflects significant advancements across various domains. AI-powered scanners enhance the accuracy of digital impressions, facilitating precise prosthetic fabrication. In treatment planning, AI analyzes patient data to support customized solutions. CAD/CAM technologies driven by AI streamline the design and production of crowns, bridges, and dentures. Diagnostic tools employing AI assist in detecting oral conditions through radiographic and intraoral image analysis. Machine learning models predict treatment outcomes, aiding clinical decision-making. Automated workflows in dental laboratories reduce manual effort and boost productivity. AI also optimizes prosthetic design for better fit and function while virtual articulators simulate jaw movement to improve accuracy. Additionally, AI accelerates research and development by providing data-driven insights. Looking ahead, AI holds great potential for fully automated prosthetic fabrication and real-time clinical guidance, shaping the future of prosthodontics. The important aspects are as follows.

1. AI in Diagnosis and Treatment Planning

Digital Imaging and Radiology: AI algorithms have been integrated into radiographic analysis, helping to identify dental conditions such as bone loss, caries, and periapical lesions. Convolutional Neural Networks (CNNs) are particularly effective in analyzing cone-beam computed tomography (CBCT) images and panoramic radiographs. Presently available AI platforms like Diagnocat helps in quick assessment of 2 dimensional or 3 dimensional radiographs [4]. Another platform Videahealth imports intraoral scans and radiographs, analyses them to formulate not only diagnosis but also a treatment plan. To add to the impact of AI, even the diagnostic equipment like CBCT machine also comes with AI enabled Safe Beam technology where AI assess the amount of radiation dose and exposure time required for a specific patient based on thickness of soft tissue and density of bone. This technology has tremendously reduced radiation exposures to the patient.

Virtual Smile Design: AI-driven software enables virtual treatment simulations, allowing prosthodontists to visualize the outcome before initiating treatment. This aids in enhancing patient communication and satisfaction. AI based platform like smiledesignpro imports images of patient and helps in planning for the contours, shade and shape of the prostheses. This not only helps clinician but also empowers patient to make decision regarding the treatment [5].

Dental Implants: There are multiple AI based platforms which allows for precision based treatment planning for dental implants [6]. The platforms helps in assessment of better diagnosis, virtual surgical planning, implant size determination and also assist in designing the final prosthesis. The currently used software like DTX Studio by Noble Biocare reduces the probability of incorrect

placement of dental implant by 50%. Another platform named Simplant imports radiographs, CBCT scans and intraoral scans. The software with AI support makes a diagnosis, treatment plan and even gives predictable prognosis of the treatment plan. Anatomage software by Invivo 5 is a platform specially used for treatment planning in case of multiple implants like All on four cases, here the platform not only assist in preparation of surgical guide but also helps to design customised abutments or attachments.

2. AI in Fabrication of Prostheses

AI plays a transformative role in the fabrication of prostheses by enhancing precision, efficiency, and customization. In prosthodontics, AI-powered CAD/CAM systems automate the design and milling of dental prostheses like crowns, bridges, and dentures, ensuring accurate fit and optimal function. Machine learning algorithms analyze patient-specific data, enabling personalized prosthetic designs that align with individual anatomical features. AI-driven 3D printing technology facilitates rapid prototyping and production, reducing turnaround times. Automated quality control systems powered by AI detect defects in real time, ensuring high standards of production. This integration of AI minimizes human error, streamlines the fabrication process, and paves the way for fully digital and patient-centered prosthetic solutions.

Computer-Aided Design and Manufacturing (CAD/CAM): AI has enhanced CAD/CAM systems by automating the design and manufacturing processes for crowns, bridges, dentures, and implant-supported prostheses. Machine learning models can analyze data from intraoral scans to predict the best design parameters, reducing human error.

3D Printing: AI enhances the precision of 3D printing technologies in prosthodontics, from optimizing printer settings to predicting material behavior during the printing process [7]. This results in better-fitting restorations and reduces the need for manual adjustments.

3. AI in Patient Management and Follow-up

AI is revolutionizing patient management and follow-up in prosthodontics by enhancing care coordination, monitoring, and personalized treatment. Intelligent scheduling systems automate appointment management, reducing administrative burdens and ensuring timely visits. AI-powered chatbots provide instant patient support, answering queries and offering pre- and post-treatment care instructions. Machine learning algorithms track patient progress by analyzing clinical data, enabling early detection of complications and personalized follow-up plans. Remote monitoring tools, integrated with wearable devices, allow continuous assessment of oral health, promoting proactive care. Through predictive analytics, AI helps forecast patient needs, improving treatment outcomes and fostering long-term patient engagement.

Tele-Dentistry and AI Chatbots: AI-powered chatbots are being used for patient follow-up, answering queries, and scheduling appointments. This ensures better patient engagement and adherence to post-treatment care [8].

Wearable AI Devices: AI integrated into wearable devices can monitor oral habits, track jaw movements, and provide real-time feedback to patients undergoing prosthodontic treatments like night guards or TMJ appliances.

4. AI Integration In Dental Lab

AI integration in dental labs has revolutionized the production of dental prostheses by enhancing efficiency, precision, and scalability. AI-powered CAD/CAM systems automate the design and milling processes, enabling the creation of highly accurate crowns, bridges,

and dentures. Machine learning algorithms optimize material selection and prosthesis design based on patient-specific data, ensuring better fit and function. Automated quality control systems inspect products in real time, reducing human error and ensuring consistent output. AI-driven 3D printing technology accelerates production, enabling same-day prosthesis fabrication. This integration streamlines workflows, minimizes manual labor, and enhances productivity, transforming traditional dental labs into fully digital production centers.

Automation of Administrative Tasks: AI systems streamline administrative functions such as appointment scheduling, billing, and inventory management through automated processes. Natural Language Processing (NLP) and machine learning models analyze and manage large volumes of data, reducing manual input and errors.

Error Detection and Correction: AI tools detect and correct design errors in real-time during the CAD process, reducing the likelihood of mistakes and improving the overall quality of the final prosthetic.

Automated Quality Inspection: AI systems equipped with computer vision algorithms inspect dental prosthetics for defects and deviations from specifications. These systems ensure that each product meets high-quality standards before it is delivered to the clinic.

Treatment planning: AI-based diagnostic tools, such as **Pearl's Second Opinion AI** and **Dentem's AIda**, help dental labs work more effectively with clinicians by offering insights into implant planning and bone structure analysis.

Advantages of AI in Prosthodontics

AI offers numerous advantages in prosthodontics, revolutionizing how clinicians diagnose, plan, and deliver care. One significant benefit is enhanced precision, as AI-powered diagnostic tools can analyze imaging data, such as radiographs and 3D scans, to detect dental issues with greater accuracy than traditional methods. This allows for early detection of conditions and more effective treatment planning. AI-driven CAD/CAM systems ensure highly accurate design and fabrication of prostheses like crowns, bridges, and dentures, resulting in a better fit and improved functionality. These technologies also significantly reduce treatment times, as automated workflows streamline traditionally labor-intensive processes, increasing efficiency and patient throughput [9].

Another advantage of AI is its ability to personalize prosthodontic care. By analyzing patient-specific data, AI can tailor treatment plans to meet individual anatomical and functional needs. Predictive analytics further improve care by forecasting treatment outcomes and identifying potential risks, enabling clinicians to make more informed decisions. In dental laboratories, AI optimizes workflows, reducing human error and ensuring consistent, high-quality production of prostheses. Beyond clinical and laboratory applications, AI also enhances patient management, offering tools for remote monitoring and virtual consultations, improving accessibility and continuity of care. Together, these advancements make AI a transformative force in prosthodontics, improving outcomes for patients and efficiencies for practitioners.

Challenges in Implementing AI in Prosthodontics

Implementing AI in prosthodontics comes with several challenges that can hinder its widespread adoption. One major obstacle is the high initial cost of acquiring advanced AI-powered equipment and integrating it into dental practices. These technologies often require significant investment in hardware, software, and maintenance. Additionally, many dental professionals

may lack the technical expertise needed to operate AI systems, necessitating specialized training and ongoing education. This learning curve can slow adoption and increase operational costs. Furthermore, compatibility issues with existing dental practice management systems can create technical barriers, complicating seamless integration.

Data privacy and security are critical concerns, as AI systems handle sensitive patient information. Ensuring compliance with healthcare data protection regulations, such as HIPAA or GDPR, requires robust cybersecurity measures [11]. Another challenge is the lack of standardized protocols and regulatory frameworks specific to AI in dentistry, leading to uncertainties in clinical validation and legal accountability [12]. Additionally, inconsistencies in data quality from different sources can affect AI accuracy, limiting its reliability in clinical applications. Addressing these challenges requires a collaborative effort from industry stakeholders, policymakers, and educational institutions to create a supportive environment for the safe and effective implementation of AI in prosthodontics.

Future Prospects of AI in Prosthodontics

The future prospects of AI in prosthodontics are promising, with continuous advancements expected to reshape clinical practice, research, and patient care. AI can play a significant role in predicting future dental issues, allowing for preventive measures [13]. For instance, predictive models can forecast wear patterns of prosthetic materials, enabling timely replacements or adjustments. AI-driven diagnostic tools are likely to become more accurate and widely adopted, enabling real-time detection of oral conditions through enhanced imaging and data analysis. The integration of AI with robotics holds potential for automated tooth preparation, implant drilling, and precise adjustments in prosthesis placement. This could reduce surgical time and improve the precision of prosthodontic procedures [14].

In dental laboratories, AI is expected to further revolutionize fabrication processes through fully automated workflows. Advanced CAD/CAM systems and 3D printing technologies will integrate more seamlessly, enabling on-demand production of highly customized prostheses. Machine learning algorithms could refine prosthetic designs by learning from vast datasets, ensuring better fit, function, and aesthetics. AI may also streamline logistics by optimizing supply chain management and inventory control, making dental labs more efficient and cost-effective. These innovations could make prosthetic treatment more accessible and affordable for patients worldwide.

Additionally, AI's role in prosthodontic education and research is set to expand [15] Dental schools may adopt AI-powered simulation platforms to train students using virtual reality and adaptive learning systems. In research, AI can accelerate discoveries by analyzing large datasets to identify trends and predict future innovations. Integration of AI with wearable devices and intraoral sensors could facilitate continuous monitoring of patients' oral health, allowing early intervention and personalized care. Moreover, AI-powered virtual treatment planning platforms will likely enable more precise and efficient design of prosthetic restorations, reducing chairside time and enhancing clinical outcomes [16]. Collaboration between AI developers, dental professionals, and regulatory bodies will be essential to establish ethical standards, ensure data security, and maintain patient trust. With these advancements, AI is poised to become a cornerstone of modern prosthodontics, driving transformative changes in clinical practice, laboratory operations, and patient-centered care.

Conclusion

In conclusion, artificial intelligence (AI) has made significant strides in prosthodontics, revolutionizing various aspects of diagnosis, treatment planning, fabrication, and patient management. The integration of AI-powered tools, such as CAD/CAM systems, diagnostic imaging software, and predictive analytics, has enhanced the precision, efficiency, and personalization of prosthodontic care. AI's ability to automate workflows, streamline lab processes, and reduce treatment times has not only improved clinical outcomes but also increased productivity within dental practices. Additionally, AI has opened new avenues for remote monitoring and patient engagement, fostering continuous care and improving patient satisfaction.

Looking ahead, the future of AI in prosthodontics holds immense potential. The continued development of more advanced AI technologies promises even greater accuracy in prosthetic design, more seamless integration with other digital tools, and improved patient care. As AI becomes increasingly embedded in dental education, research, and clinical practice, it is expected to drive further innovation and accessibility in prosthodontic treatments. However, addressing challenges such as data privacy, integration complexities, and the need for specialized training will be essential to fully harness AI's potential. Ultimately, AI is poised to be a transformative force in prosthodontics, contributing to enhanced clinical practices, better outcomes for patients, and more efficient workflows in dental laboratories and clinics.

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