REVIEW ARTICLE

Precision Smiles 2.0: Revolutionizing Prosthodontics with Artificial Intelligence Ingenuity

Seba Sara Geevarghese[1], Anu Girdhar[2], Navneet Kaur Mann[3], Samuel Prasad Cherian[4]

Received on: 01 November 2023; *Accepted on:* 22 November 2023; *Published on:* 30 December 2023

Abstract

Artificial intelligence (AI) is revolutionizing prosthodontics, transforming various aspects from treatment planning to implant procedures and maxillofacial prosthetics. This article is a review that emphasizes the current applications of AI in prosthodontics, highlighting its benefits in efficiency, accuracy, and patient satisfaction. Artificial intelligence has the potential to significantly improve the quality and efficiency of prosthodontic care, paving the way for a future of personalized and predictable dentistry. Applications of AI from treatment planning and digital impression acquisition to implant procedures and maxillofacial prosthetics fabrication.

As AI improves efficiency, accuracy, and patient satisfaction it enhances productivity and reduces the time involved in fabricating the prosthesis through different software. There are many challenges associated with widespread AI adoption, such as cost and training requirements. The article concludes by stressing the need to embrace AI's potential and facilitate its seamless integration into prosthodontic practice, paving the way for a future of predictable, safe, and efficient dentistry.

Keywords: Artificial intelligence, Augmented/virtual reality, CAD-CAM, Implants, Maxillofacial prosthetics, 3D Printing.

Dental Journal of Advance Studies (2023): 10.5005/djas-11014-0028

Introduction

Artificial intelligence (AI) is described as "a branch of science and engineering concerned with the computational understanding of what is often referred to as intelligent behavior and the development of artifacts that display such behavior".[1] Artificial intelligence is a technology that uses machines to imitate intelligent human behavior. The incorporation of artificial intelligence and digitization in the field of health care has upgraded the standards of services provided. The breakthrough of AI in the field of dentistry has created a significant impact on progressive outcomes. Beginning with patient documentation, AI helps in diagnosis, decision-making, treatment planning, as well as prediction of treatment outcomes.[2]

Various attributes of artificial intelligence include:

- Autonomous operation: Automation of tasks ranging from laborious manpower to the recruitment process with the help of AI can ease the complexities of tedious manual tasks. This can contribute to focusing on more important and complex tasks.
- Increased performance: Automation helps with minimum effort, maximum efficiency, increased performance, and time management.
- Smart decision making: Artificial intelligence is a technology that uses machines to imitate intelligent human behavior. Machine learning focuses on applying algorithms derived from former cases, which help decision-making and ensure accuracy.
- Addressing intricate challenges: Navigating intricate issues demands a blend of critical thinking and innovative solutions. Healthcare demands solutions to such complex challenges, which might involve diagnosis, correlating clinical findings, or treatment planning.

Artificial Intelligence in Prosthodontics

Prosthodontics is the art and science of dentistry that deals with the diagnosis, treatment planning, rehabilitation, and preservation of the oral structures function, comfort, aesthetics, and health of patients with clinical problems associated with missing or deficient teeth and oral and maxillofacial tissues.[3]

The main areas of focus for AI in prosthodontics are:

- Implant procedures.[4–10]
- Maxillofacial prosthesis construction.
- Finishing margin preparation alongside the tooth for improved prosthesis fitting and extension.
- Treatment of both fixed and removable dental prostheses.

In prosthodontics, initially, the AI model was designed to help fabricate monolithic zirconia crowns in fixed implant prostheses.[11] The application of AI to assist in determining the subgingival margin of the abutment lets the dentist focus more on preserving tooth preparation and occlusal and interproximal interactions. Thus, the goal was to reduce errors and time consumed.

Methods

Over the past few decades, prosthetic fabrication has used three-dimensional (3D) digital technologies to enhance these conditions.

[1–3]Department of Prosthodontics, National Dental College, Dera Bassi, Mohali, Punjab, India

[4]Department of Public Health, School of Health System Studies, Tata Institute of Social Sciences, Mumbai, Maharashtra, India

Corresponding Author: Seba Sara Geevarghese, Department of Prosthodontics, National Dental College, Dera Bassi, Mohali, Punjab, India, Phone: +91 8558857998, e-mail: zionrose1705@gmail.com; zionarreahrose@gmail.com

How to cite this article: Geevarghese SS, Girdhar A, Mann NK, *et al*. Precision Smiles 2.0: Revolutionizing Prosthodontics with Artificial Intelligence Ingenuity. Dent J Adv Stud 2023;11(3):131–134.

Source of support: Nil

Conflict of interest: None

The manufacturing method for maxillofacial prostheses has effectively included 3D scanning, CAD, and 3D printing.[12,13]

Deep learning, a branch of AI, has advanced rapidly over the recent years and has shown promise in handling challenging tasks related to medicine, particularly the analysis of medical images. Artificial neural networks (ANNs), a machine learning technique inspired by biological neural networks, are used by deep learning algorithms. An ANN comprises an output layer, hidden layers, and an input layer that takes in input signals. Since deep ANNs have a large number of hidden layers, they can attain excellent accuracy. Studies conducted in the dentistry field have employed AI to diagnose patients based on radiographic images, such as cone-beam computer tomographic, periapical, and cephalometric radiographs. Along with image sorting, deep learning can be used to forecast disease progression and plan medical interventions.[14–16]

Scope of Artificial Intelligence in Prosthodontics

Treatment Planning

Artificial intelligence is revolutionizing prosthodontics, impacting various aspects from treatment planning to digital impression acquisition. By analyzing radiographs, CBCTs, and panoramic images, AI can assess the patient's condition, correlate clinical symptoms, and predict treatment outcomes with greater accuracy. As a result, patients can receive more customized and efficient treatment plans and provide visualization tools that help them comprehend their choices and make informed decisions. Furthermore, AI-powered digital impressions provide better precision, higher efficiency, a decrease in human error, and a more pleasant experience for patients.[17,18]

Digital Impression

AI-powered digital impressions offer superior accuracy, increased efficiency, reduced manual error, and a more pleasant experience for patients. This data is then stored as STL files, facilitating future reference and analysis, further enhancing the scope of AI in prosthodontics.

Instantaneous evaluation of digital impressions, identifying inconsistencies, and providing immediate feedback in real-time can be done with the help of: (1) augmented reality (AR) or virtual reality (VR), (2) cloud-based platforms, (3) integrated software solutions, (4) internet of things (IoT) integration.

Artificial intelligence can minimize mistakes and significantly shorten the impression acquisition time, greatly boosting the efficiency of the process. Various methods that can be utilized are: (1) intraoral scanners, (2) real-time visualization, (3) guided scanning technology, (4) automated alignment and stitching, (5) cloud-based processing, (6) integrated computer-aided design/computer-aided manufacturing (CAD/CAM).

Prosthetic Design and Fabrication

Artificial intelligence leverages insights from data analysis to recognize possible challenges and risks, enabling proactive measures to reduce errors in restorative procedures. Performs instantaneous evaluations throughout the fabrication phase, ensuring accurate compliance with predefined specifications and thereby ensuring optimal outcomes. Artificial intelligence-driven systems guarantee the precise milling or 3D printing of prosthesis materials, maintaining the utmost precision standards. It helps in (1) high-resolution 3D printing, (2) CAD/CAM Integration, (3) CNC and multi-axis milling machines, (4) material selection and in-process quality control, (5) digital inspection technologies, (6) skill development and technical advancement.

Discussion

Artificial intelligence functions as a collaborative assistant, supporting case planning through data analysis and potentially providing recommendations from an extensive knowledge repository. It has largely created a difference by playing a major role in diagnosis and treatment planning, streamlining protocols, greater patient dedication, safer procedures, precision in procedures, execution of treatment, superior selection of materials and technologies, and even prediction of the treatment outcome.

Implantology and Artificial Intelligence

In research by Lee J et al., panoramic and periapical radiography were utilized to classify implants using convolutional neural networks (CNNs) based on AI. Based on the results of this study, the AI-CNN system is virtually as effective as humans in classifying implant methods.

Artificial intelligence models in implant dentistry can be used for implant type recognition, implant success prediction by using patient risk factors, implant design optimization combining finite element analysis (FEA) calculations and AI models.[19] AI models for implant type recognition, implant success prediction, and implant design optimization have demonstrated great potential but are still in development.

Maxillofacial Prosthodontics and Artificial Intelligence

"Smart reading glasses," which are voice-activated gadgets that can be attached to any pair of glasses, are designed primarily to help blind and visually challenged people. It can quickly read text from a book, smartphone screen, or any other surface, identify faces, work more effectively, and help its user lead an independent life. "Bionic eye," created in the United States, utilizes artificial intelligence to help patients who have lost their sightsee without surgery. A smart camera on special glasses lets the user read text or recognize faces. An AI expert observes the data from the camera and turns it into sound through a wireless earpiece. The inability to feel when limbs are cut off can be compensated by a tissue made of a thin, see-through layer of water and pectin, which can sense changes in temperature between 5 and 50°C. Artificial olfaction can be made possible with the help of electronic nose models. This new dimension can be given because four chemical sensors that categorize, identify, and recognize scents are based on the signal combination pattern that emerges in the ensemble of each receptor.

Skin tissue engineering is a contemporary medical practice that aims to create bioprinter biomaterial-based synthetic skin grafts. Over the past two decades, osseointegrated implants have been used to enhance craniofacial retention.[19–22] Various systems that are currently available in the market include bar and clip systems, magnets, mushroom, and ball retention methods. Also, these prostheses can now be fabricated using digital technologies.

The creation of maxillofacial prosthesis utilizing CAD/CAM technology starts with imaging techniques that record the patient's soft and hard tissues. Software is subsequently used to transform this data into an RP model. Then, utilizing reproduction techniques, the RP models are transferred into wax directly or in acrylic resin. The silicone elastomer prosthesis can be built from the cast. This approach needs less time than the conventional approach.[23,24]

Artificial intelligence algorithms can be trained to analyze digital impressions instantly. Machine learning models can identify potential discrepancies, errors, or areas of concern based on predefined criteria. These AI systems could provide immediate feedback to the clinician.

- **Augmented reality or virtual reality:** Augmented reality or virtual reality technologies could be integrated into the digital impression process. Dentists or technicians might wear AR or VR devices to visualize the impressions in real-time, with the system highlighting any discrepancies or providing guidance on adjustments.[25]
- **Cloud-based platforms:** Storing digital impressions on cloud-based platforms enables remote access and collaborative assessment. Experts or AI systems located elsewhere could review the impressions in real-time and provide instant feedback to the on-site clinician. Offloading the processing and analysis of digital impressions to cloud-based platforms enables faster computation and access to advanced algorithms. This can substantially reduce the time taken to generate the final digital model, contributing to overall efficiency.
- **Integrated software solutions:** Dental CAD/CAM software could be enhanced to include real-time assessment modules. The software might automatically analyze the digital impressions and generate instant reports, flagging any issues for the operator.
- **Internet of things integration:** If the devices used for digital impressions are IoT-enabled, they could transmit data in real-time to a centralized system for assessment. This data could then be processed by AI algorithms or reviewed by experts who provide immediate feedback.
- **Intraoral scanners:** Modern intraoral scanners use advanced optical technology to capture detailed 3D images of the oral cavity quickly and with high precision. These scanners eliminate the need for traditional impression materials and trays, reducing the chances of errors associated with traditional molds.[26]
- **Real-time visualization:** Some digital impression systems provide real-time visualization of the scanning process on a computer screen. This allows the clinician to immediately identify any areas that need to be rescanned or adjusted, minimizing the likelihood of errors and streamlining the overall workflow.
- **Guided scanning technology:** Guided scanning technology assists clinicians by providing visual or auditory cues during the scanning process. This helps ensure comprehensive coverage of the oral anatomy and reduces the chances of missing critical details**.**
- **Automated alignment and stitching:** Advanced software algorithms automatically align and stitch together individual scan images, creating a seamless and accurate 3D model of the patient's oral anatomy. This reduces the time required for manual post-processing and enhances the overall efficiency of the digital impression workflow.
- **CAD/CAM integration:** Integration with CAD/CAM systems ensures seamless communication between the design and manufacturing phases. CAD/CAM systems allow for precise digital modeling of the prosthesis and generate machine-readable instructions for milling or 3D printing.
- **Computer numerical control and multi-axis milling machines:** Computer numerical control (CNC) milling machines equipped with high-precision tools and mechanisms are used for milling prosthesis materials such as ceramics, metals, or composite resins. These machines are capable of intricate milling processes with micron-level accuracy. Milling machines with multiple axes (3-axis, 4-axis, or 5-axis) provide greater flexibility in producing complex geometries. Multi-axis milling allows for the precise shaping of prosthesis materials from various angles, reducing the need for manual adjustments.
- **Quality control and material selection:** Implementing in-process quality control measures during milling or 3D printing is crucial for detecting and correcting any deviations from the desired precision standards. This may involve real-time monitoring, feedback loops, and automated inspections. Choosing high-quality prosthesis materials that are suitable for milling or 3D printing is essential. The material properties, including strength, biocompatibility, and stability, should meet the specific requirements of the intended application.[27]
- **Digital inspection technologies:** Implementing digital inspection tools, such as coordinate measuring machines (CMM) or optical scanners, can verify the accuracy and dimensions of the milled or 3D printed prosthesis against the digital design, providing an additional layer of quality assurance.
- **Skill development and technical advancement:** Ensuring that the operators and technicians are well-trained and updated on the latest technologies and best practices is vital for maintaining precision standards in manufacturing.[28]

Artificial Intelligence Tools

Technology	*Functions*	*AI tool*
CAD/CAM SOFTWARE	Design and manufacture prosthetics	Dental Wings, CEREC, Exocad, etc.
Diagnostic imaging	Analyze radiographic data for diagnosis and treatment planning	Dentsply Sirona Sidexis XG, Carestream
Patient monitoring apps	To monitor oral health, early identification of complications	Bioserenity's pain diagnostics
Patient data management	Managing patient information and identifying risk factors	Open dent, Eaglesoft, CS web, etc.
Training and decision support systems	Training and decision support to dentists	
Aesthetic simulation	Prosthetic rehabilitations, visualization of final outcome	Digital Smile Design, Smile styler, etc.

Conclusion

Prosthodontics is poised to experience a revolution. Consequently, it is essential to embrace AI's revolutionary potential. Artificial intelligence highlights significant improvements in efficiency, accuracy, and patient satisfaction.

Even with the progress that has been made, it is crucial to address the issues that might arise in future. The large expense and the need for good training to make the most of this are only two of the numerous barriers preventing widespread adoption. Although the domain AI has created in the field of dentistry is powerful, the expertise of the dental professional is indispensable. As we proceed, our top priorities should be promoting innovation and facilitating prosthodontist's smooth integration with AI. This depicts a bright future where AI augments traditional techniques and changes

them, leading to predictable, safer and more efficient dentistry that could guarantee patient satisfaction.

References

1. Shapiro SC. Encyclopedia of Artificial Intelligence, 2nd edition, New Jersey, NY: USA, Wiley; 1992. pp. 641–663.
2. Karchi RP, Nagaraj E, Kondody RT, et al. Artificial Intelligence in Prosthodontics: New Paradigm Shift. IOSR Journal of Dental and Medical Sciences 2023;22(7):06–09. DOI: 10.9790/0853-2207060609.
3. The Glossary of prosthodontic terms: Ninth edition. J Prosthet Dent 2017;117(5S):e1–e105. DOI: 10.1016/j.prosdent.2016.12.001.
4. Bhatia AP, Tiwari S. Artificial intelligence: An advancing front of dentistry. Acta Sci Dent Sci 2019;3(12):135–138. DOI: 10.31080/ASDS.2019.03.0714.
5. Cicciù M. Prosthesis: New technological opportunities and innovative biomedical devices. Prosthesis 2019;1(1):1–2. DOI: https://doi.org/10.3390/prosthesis1010001.
6. Minervini G, Fiorillo L, Russo D, et al. Prosthodontic treatment in patients with temporomandibular disorders and orofacial pain and/or bruxism: A review of the literature. Prosthesis 2022;4(2):253–262. DOI: https://doi.org/10.3390/prosthesis4020025.
7. Cicciù M, Cervino G, Terranova A, et al. Prosthetic and mechanical parameters of the facial bone under the load of different dental implant shapes: A parametric study. Prosthesis 2019;1(1):41–53. DOI: https://doi.org/10.3390/prosthesis1010006.
8. Cicciù M. Past, present and future of prosthesis: 2020 upgrade. Prosthesis 2021;3(1):9–10. DOI: https://doi.org/10.3390/prosthesis3010002.
9. Chaturvedi S, Alqahtani NM, Addas MK, et al. Marginal and internal fit of provisional crowns fabricated using 3D printing technology. Technol. Health Care 2020;28(6):635–642. DOI: 10.3233/THC-191964.
10. Alsubaiy EF, Chaturvedi S, Qutub OA, et al. Novel CAD-CAM zirconia coping design to enhance the aesthetics and strength for anterior PLZ crowns. Technol Health Care 2021;29(6):1161–1171. DOI: 10.3233/THC-202782.
11. Lerner H, Mouhyi J, Admakin O, et al. Artificial intelligence in fixed implant prosthodontics: A retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients. BMC Oral Health 2020;20(1):80. DOI: 10.1186/s12903-020-1062-4.
12. Shan T, Tay FR, Gu L. Application of artificial intelligence in dentistry. J Dent Res 2021;100(3):232–244. DOI: 10.1177/0022034520969115.
13. Raith S, Vogel EP, Anees N, et al. Artificial neural networks as a powerful numerical tool to classify specific features of a tooth based on 3D scan data. Comput Biol Med 2017;80:65–76. DOI: 10.1016/j.compbiomed.2016.11.013.
14. Howard J. Artificial intelligence: Implications for the future of work. Am J Ind Med 2019;62(11):917–926. DOI: 10.1002/ajim.23037.
15. Varian H. Artificial intelligence, economics, and industrial organization. In: The Economics of Artificial Intelligence. Chicago: University of Chicago Press; 2019. pp. 399–422. DOI: https://doi.org/10.7208/9780226613475-018.
16. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: A review of the available streams. Int J Dent 2014;2014:783948. DOI: 10.1155/2014/783948.
17. Lee JH, Jeong SN. Efficacy of deep convolutional neural network algorithm for the identification and classification of dental implant systems, using panoramic and periapical radiographs: A pilot study. Medicine (Baltimore) 2020;99(26):e20787. DOI: 10.1097/MD.0000000000020787.
18. Hosny A, Parmar C, Quackenbush J, et al. Artificial intelligence in radiology. Nat Rev Cancer 2018;18(8):500–510. DOI: 10.1038/s41568-018-0016-5.
19. Lee JH, Kim DH, Jeong SN, et al. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent 2018;(77):106–111. DOI: 10.1016/j.jdent.2018.07.015.
20. Aydin C, Karakoc S, Yilmaz H, et al. Implant retained auricular prostheses: An assessment of implant success and prosthetic complications. Int J Prosthod 2008;21(3):241–244. PMID: 18548964.
21. Susic I, Travar M, Susic M. The application of CAD/CAM technology in dentistry. IOP conf ser: Mater Sci Eng 2017;(200):12–20. DOI: 10.1088/1757-899X/200/1/012020.
22. Ciocca L, Minggucci R, Gassino G, et al. CAD/CAM ear model and virtual construction of the mold. J Prosthet Dent 2007;98(5):339–343. DOI: 10.1016/S0022-3913(07)60116-4.
23. Grischke J, Johannsmeier L, Eich L, et al. Towards robotics and artificial intelligence in dentistry. Dent Mater 2020;36(6):765–778. DOI: 10.1016/j.dental.2020.03.021.
24. Verdonck HW, Poukens J, Overveld HV, et al. Computer-assisted maxillofacial prosthodontics: A new treatment protocol. Int J Prosthodont 2003;16(3):326–328. PMID: 12854800.
25. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in oral and maxillofacial surgery. BMC Oral Health 2019;19(1):238. DOI: https://doi.org/10.1186/s12903-019-0937-8.
26. Amornvit P, Rokaya D, Sanohkan S. Comparison of accuracy of current ten intraoral scanners. Biomed Res Int 2021:2021:2673040. DOI: 10.1155/2021/2673040.
27. Chen YW, Stanley K, Att W. Artificial intelligence in dentistry: Current applications and future perspectives. Quintessence Int 2020;51(3):248–257. DOI: 10.3290/j.qi.a43952.
28. Woo SY, Lee SJ, Yoo JY, et al. Autonomous bone reposition around anatomical landmark for robot assisted orthognathic surgery. J Cranio-Maxillo-Facial Surg 2017;45(12):1980–1988. DOI: 10.1016/j.jcms.2017.09.001.