Global Academic Journal of Dentistry and Oral Health

Available online at https://www.gajrc.com
DOI: 10.36348/gajdoh.2023.v05i02.001

OPEN ACCESS

ISSN-2706-8994 (P)
ISSN-2707-8868 (O)

Review Article

Artificial Intelligence in Prosthodontics and Oral Implantology – A Narrative Review

Dr. Arpit Sikri[1*], Dr. Jyotsana Sikri[2], Dr. Rimple Gupta[3]

[1]Associate Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

[2]Associate Professor & Post Graduate Teacher, Department of Conservative Dentistry & Endodontics, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

[3]Senior Lecturer, Department of Conservative Dentistry and Endodontics, Luxmi Bai Institute of Dental Sciences and Hospital, Patiala (Punjab), India

***Corresponding Author**
Dr. Arpit Sikri
Associate Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

Article History
Received: 05.04.2023
Accepted: 12.05.2023
Published: 16.05.2023

Abstract: Dentistry incorporating artificial intelligence (AI) is becoming a reality and not just a myth. By using machines to mimic intelligent human behaviour, AI has significantly changed the medical and dental fields. This contemporary and information-driven innovative technology is gaining worldwide popularity due to its significant impact on intelligence innovation. AI is a lifesaver in dentistry, specifically in prosthodontics, which involves the restoration and reconstruction of missing teeth using implants for permanent and removable prostheses. The technology aids in designing prostheses, fabricating functional maxillofacial appliances, patient documentation, diagnosis, treatment planning, and patient management, allowing oral healthcare professionals to work more efficiently. AI cannot, however, take the position of a dental surgeon because their work requires more than just diagnosing diseases; it also entails treating patients and correlating findings with other clinical data. A new paradigm in dentistry has emerged because of the integration of AI and digitization, with potential futures. Dental surgeons should concentrate on gathering and entering accurate data into their database for AI usage in dentistry shortly to get beyond the only obstacle to the deployment of AI, which is the availability of insufficient and inaccurate data. To diagnose problems and develop patient-specific prostheses, the present narrative review article examines numerous uses of AI in prosthodontics and oral implantology, as well as its current limitations and potential future applications.

Keywords: Artificial intelligence, CAD/CAM, implantology, maxillofacial prostheses, prosthodontics.

INTRODUCTION

Digitalization has rapidly spread across many aspects of life, making living easier. This revolution has transformed dentistry and improved the quality of care. Since the beginning of recorded history, the functioning of the brain has fascinated people, and various technologies have attempted to replicate it [1]. Artificial intelligence (AI) is the result of years of effort to accurately imitate the workings of the human brain. AI is defined as a branch of science and engineering concerned with the computational understanding of intelligent behaviour and the development of artefacts that display such behaviour [2]. AI and machine learning have influenced several domains of science and engineering. Machine learning is a special branch of

AI where the system learns statistical patterns in a data set to predict the behaviour of new data samples. Machine learning systems offer a variety of algorithms and methods that are suitable for complex prediction tasks by recognizing and capturing statistical patterns in a data set. Machine learning algorithms use two types of training: supervised and unsupervised. Supervised training involves input-output pairs of training data for tasks such as classification and regression, while unsupervised training captures important features in a given data set for tasks such as clustering and dimensionality reduction. Deep learning, based on artificial neural networks, is an advanced methodology that has found applications in many domains due to its exceptional ability for generalization [3].

The applications of AI in various industries include expert systems, game playing, picture recognition, natural language processing, robotics, and theorem-proving in telecommunications and aerospace. The advancements in technology have also brought significant changes in medicine and dentistry in the past decade. By utilizing AI, dental healthcare professionals can reduce the workload and the need for more staff, making it a valuable tool in the field [4].

Machine learning-enabled decision support systems can utilize the vast amount of data in healthcare systems to provide optimal learning sources for healthcare practitioners. These systems can help sort out the complexities of clinical variabilities and increase diagnostic accuracy. The development of cloud computing, data processing, and the availability of massive amounts of data have led to the increasing adoption of AI in healthcare and dentistry. Radiology, for instance, has benefited from the use of a specific algorithm that aids in diagnosing and providing potential treatment options. AI has the potential to be utilized in several fields of dentistry, including prosthodontics, orthodontics, oral surgery, and periodontics for condition analysis and treatment planning [5].

Indeed, AI has a vast potential to revolutionize the field of prosthodontics. Machine learning algorithms can analyze patient data and predict the best treatment plan for each individual patient based on their unique needs and conditions. For example, AI can be used to design and fabricate customized dental prostheses such as crowns, bridges, and dentures that perfectly fit a patient's mouth and function optimally [6]. This is particularly important in cases where patients have unique or complex dental structures that require a more personalized approach. AI can also aid in implant surgery by accurately planning the placement and orientation of dental implants based on factors such as bone density and proximity to nerves and blood vessels. This can help reduce the risk of complications and improve the overall success rate of the procedure. Overall, AI has the potential to greatly enhance the precision, efficiency, and effectiveness of prosthodontic treatments, ultimately improving the overall quality of care for patients [7]. The present narrative review study can be a valuable resource for dental surgeons and researchers who want to explore the potential benefits of AI in the field of prosthetic dentistry and oral implantology.

DISCUSSION

The review article discusses the various applications of AI in prosthetic dentistry and oral implantology, including CAD/CAM systems, implant prostheses, and studies of orofacial anatomy. The use of AI technology in prosthodontics can aid in the synoptic treatment idea, sufficient backward planning, and clean practical execution of prosthetic reconstruction. One example of using prosthetic AI is the diagnosis of periodontal deficient premolars and molars with high accuracy [8]. However, the limitations of AI in dentistry are also acknowledged, such as the inability to distinguish between early lesions or offer a conclusive diagnosis of periodontal disease due to the redundancy of imaging characteristics and the visual field of periapical radiographs. Overall, the review highlights the potential benefits of AI in improving prosthodontic care and calls for further research in this area.

Application of AI in Prosthodontics

Artificial intelligence (AI) can assist in many aspects of prosthodontics, such as treatment planning, rehabilitation, and prosthetic replacement. AI can help in predicting the success rate of dental implant surgery, identifying the most suitable type of prosthesis for a patient, and providing accurate shade selection for the prosthesis to enhance its appearance. AI can also help in the diagnosis of periodontal disease and tooth decay, and in identifying and analyzing orofacial anatomy. The use of AI in prosthodontics can improve the accuracy and efficiency of diagnosis and treatment planning, leading to better outcomes for patients [9].

AI and removable dental prosthesis

AI can be used in the fabrication process of RPDs through 3D printing technology. 3D printing technology enables the fabrication of RPDs in a more efficient, accurate, and cost-effective manner compared to traditional methods. AI algorithms can also aid in the development of a more personalized and customized approach to RPD design, as it can analyze patient data and create a design that is unique to the individual patient's needs and

anatomy [10]. Furthermore, AI can be used in the evaluation of RPD fit and function. Computer-aided analysis of RPD fit can provide accurate measurements and assessments of the prosthesis' fit, occlusion, and overall function. This can aid in the diagnosis and correction of any issues with the prosthesis, leading to improved patient satisfaction and outcomes [11].

In summary, AI has the potential to revolutionize the design and fabrication process of RPDs, leading to more personalized and efficient treatment options for patients with partial edentulism. Its use in the evaluation of RPD fit and function can also lead to improved patient outcomes and satisfaction [12].

AI and fixed dental prosthesis

The use of AI in fixed prosthodontics can also help in improving the accuracy and efficiency of tooth preparation. AI algorithms can analyze and learn from a large database of successful crown designs, providing insights into the optimal contour, extension, and marginal line surrounding the teeth for each case. In addition, AI can assist in the tooth margin preparation process by automating the extraction of marginal lines with precision, which traditionally required advanced technical skills and time-consuming manual labor. A study by Zhang *et al*., [13] utilized a deep learning model to extract marginal lines with high accuracy. The study utilized a convolutional neural network (CNN) model called Sparse Octree (S-Octree) and achieved an average precision of 97.43%. These findings demonstrate AI's potential to improve the accuracy and efficiency of tooth preparation in fixed prosthodontics.

AI and Maxillofacial Prostheses

AI has been making significant contributions to the field of maxillofacial prosthodontics. By using convolutional neural networks (CNNs) to mimic human neurons, AI-powered prosthetic devices can help patients with maxillofacial abnormalities or injuries to restore both their function and aesthetics. For instance, AI-powered prosthetic eyes can help patients see without surgery, while smart reading glasses with voice-activated technology can assist the visually challenged in reading text and identifying faces [14].

In addition, tissue engineering has also been utilizing AI to develop skin replacements for wound regeneration. Artificial skin grafts can provide temporary wound coverings or long-term skin replacements, and their primary functions are to give oxygen, prevent dehydration, promote healing, and guard against infections [15].

Another field where AI has shown its potential is in artificial olfaction, which has been captivating scientists for about four decades. The electronic nose model is an example of an artificial olfactory system that mimics the human olfactory detection system using a variety of electronic sensors. This technology can be used in various sectors, such as disease diagnosis, environmental monitoring, public safety issues, the food industry, and agricultural production [16].

AI and Implant Prosthodontics

AI has been used to optimize implant placement and planning by analyzing CBCT images and creating a 3D model of the patient's jawbone. This can help to identify the ideal location and angle for implant placement, which can improve the overall success rate of the procedure [17]. AI algorithms have also been used to detect bone quality and quantity, which is crucial for implant success. By using AI to analyze CBCT images, clinicians can obtain measurements that are more accurate and detect areas of potential bone loss or pathology [18].

AI has also been used in implant dentistry to predict implant stability and success rates. By analyzing patient data and factors such as bone density, implant length, and implant diameter, AI algorithms can predict the probability of implant success [19]. This can help clinicians to make more informed decisions when planning implant procedures, and can provide patients with more accurate information about the potential outcomes of their treatment.

The use of AI in implant dentistry has the potential to improve treatment planning, implant placement, and overall success rates. By analyzing patient data and images, AI algorithms can provide clinicians with valuable insights that can help to optimize treatment outcomes. However, it is important to note that AI should be used as a tool to assist clinicians, rather than as a replacement for human expertise and decision-making [20].

The use of digital technology in implantology has revolutionized the field, allowing for precise planning and placement of implants, as well as the design and fabrication of prostheses. Digital planning software allows clinicians to create a virtual surgical guide that can be used to guide implant placement during surgery. Rapid prototyping technology can then be used to create the physical surgical guide, which can be used during surgery to ensure accurate placement of the implants. This approach allows for greater accuracy and precision in implant placement, reducing the risk of complications and improving the overall

success rate of the procedure. Overall, the use of digital technology in implantology and prosthodontics has transformed the field, allowing for greater precision, accuracy, and customization in treatment planning and implementation [21].

In a study by Lee J *et al*., [22], convolutional neural networks (CNNs) based on AI were used to categorise implants using panoramic and periapical radiography. According to the study's findings, the AI-CNN system is almost as good at categorising implant procedures as humans are. Takahashi *et al*., [23] conducted a thorough investigation to create an AI framework that would classify dental arches and make use of CNN to help with denture production. The training dataset was categorised using methodologies for computer-based autonomous learning. Several issues might arise when typical CAD/CAM methods are used for cementing implant prostheses. Errors may result from incorrect positioning, improper cementation, or incorrect occlusal or interproximal correction with an abutment. An AI model was presented by Lerner *et al*., [24] to minimise these errors. In order to facilitate the development of fixed implant prostheses with monolithic zirconia crowns, this AI model was created. The application of an AI model to help find abutment subgingival margins. Additionally, this model let the dental surgeon concentrate on tooth preparation and preserve interproximal and occlusal contacts. The purpose of this convenience was to reduce mistakes and wait times. The study employing zirconia implant prostheses in the posterior teeth used patient data from 2016 to 2019. Ninety patients participated in the trial, with a male to female ratio of 7:11. There were 106 implants total in this study. Among the data sets used to create AI models (images) were radiographs, photographs, CAD scenes, and intraoral scans. With a survival rate of 91% and a success rate of 93%, the employment of an AI model in the manufacturing of zirconia implants for the posterior teeth produced encouraging results. The findings of the AI model showed a high survival and success rate, which proved the model's suitability for this field [25].

The use of AI in implant dentistry has allowed for more accurate and efficient planning of surgeries, with the ability to combine multiple types of scans and data to create customized treatment plans for each patient. This can help ensure the success of the implant procedure and improve patient outcomes [26].

Predictive AI models can be used in two areas of dental implantology. The first area is the prediction of clinical outcomes using machine-learning algorithms. A recurrent artificial neural network (ANN) with memetic search optimization can simultaneously evaluate patient data, implant systems, and surgeon operations to predict success rates with 99.2% efficiency [27]. The second area is the use of AI to anticipate the mechanical properties of bioimplant systems, reducing the computational cost involved in improving implant design variables [28]. However, more research is needed to further develop AI in the risk optimization of bioimplants.

AI and CAD/CAM

The use of intraoral scanners, CAD/CAM technology, and AI in prosthetic dentistry has revolutionized the way dental restorations are designed and fabricated. These advancements have made the process faster, more accurate, and less labour-intensive. The use of AI in margin detection and designing prostheses has improved the overall quality of the restorations. With the integration of AI and CAD/CAM, prostheses can be customized to each patient's unique needs, resulting in improved aesthetics and function. Additionally, the use of AI and CAD/CAM technology in removable denture design and manufacture has simplified laboratory operations, reduced human error, and minimized overall patient rehabilitation time [29].

AI and aesthetic dentistry

However, with the development of digital tools and technologies, smile designs are now created using digital software, which allows for more accurate and precise planning. This has resulted in more predictable and aesthetically pleasing outcomes for patients. Virtual smile design software allows dental professionals to customize each aspect of a patient's smile, from the shape and size of their teeth to the colour and position. This customization helps create a unique smile that suits the patient's facial features and personality [30].

Moreover, digital tools have also revolutionized the orthodontic field. Orthodontists can use digital software to simulate tooth movement and predict the outcome of orthodontic treatment. This allows them to create a customized treatment plan for each patient, which can save time and reduce the number of office visits required. Digital tools have also made it possible for orthodontists to create clear aligners, such as Invisalign, which are custom-made for each patient using 3D printing technology [31].

In summary, digital tools and technologies have transformed the field of dentistry, from diagnosis and treatment planning to the creation of prosthetic restorations and orthodontic appliances. With the integration of AI and machine learning, the potential for digital dentistry to improve patient

outcomes and reduce treatment time continues to grow [32].

AI and occlusion

AI has opened up several innovative opportunities in prosthetic dentistry. For example, in crown contemplation, AI can generate the occlusal morphology of the crown based on the opposing teeth, even in cases of wear or fracture. This helps to ensure a proper fit and function of the crown. Similarly, AI can also be used for programmed teeth setting in dentures, which ensures a proper bite and function of the denture. Additionally, AI can be used for automatic framework designs for removable dental prostheses, reducing the time and effort required in the design process. All of these applications can help to improve the accuracy and efficiency of prosthetic dentistry procedures, leading to better patient outcomes [33].

AI and education

AI can be used as an educational tool to guide dental students, both at the undergraduate and postgraduate level. AI can assist in teaching various aspects of dentistry, such as diagnosis, treatment planning, and even the execution of procedures. For example, virtual simulators can be used to help dental students practice procedures in a safe and controlled environment, allowing them to hone their skills before performing procedures on real patients. AI-powered educational software can also provide personalized learning experiences for each student, tailoring the curriculum to their individual needs and abilities. Additionally, AI can assist in grading and assessment, providing objective and standardized evaluations of students' performance [34].

Limitations of AI

Furthermore, the integration of AI in prosthodontics raises ethical concerns. There are concerns about patient confidentiality and privacy, as well as the ethical implications of AI-generated diagnoses or treatment plans. AI may be programmed with biases that lead to discriminatory or unfair outcomes. There are also concerns about the potential loss of jobs for dental technicians, as AI takes over their tasks. To address these issues, it is important for dental professionals to be aware of the limitations and potential biases of AI technology. They must also ensure that they are using high-quality data and that their algorithms are regularly monitored and updated. Additionally, ethical guidelines and regulations should be established to ensure that AI is used in a responsible and beneficial manner [35].

Standardizing methodology in data collection and reporting is indeed critical to improving the quantity, quality, and readability of data in dentistry. The creation of a standard open-access dataset that includes complete clinical, experimental, and therapeutic data would be a significant step in the next stage of AI research, allowing for the analysis and comparison of various algorithms. This would enable researchers to build better models and train them more efficiently, ultimately leading to improved patient care and outcomes. Additionally, as more dental practices adopt digital technologies, such as electronic health records and imaging systems, the volume of data available for AI training and research is expected to increase significantly. This highlights the need for a robust data infrastructure and standards to support AI development and deployment in dentistry [36].

Quantum computing has the potential to greatly enhance AI applications by providing a more powerful and efficient platform for processing large and complex data sets. Compared to classical computers, which rely on binary digits (bits) that can exist in only one of two states (0 or 1), quantum computers use qubits that can exist in multiple states simultaneously, allowing for much faster and more efficient processing of data. This has significant implications for AI, particularly in the areas of machine learning and data modelling, where the ability to process vast amounts of data quickly and accurately is critical. However, quantum computing is still in its early stages, and much research is needed to develop practical and scalable quantum computing systems for widespread use [37].

Interpretability is crucial in the field of AI in healthcare because it helps build trust between practitioners and the technology. If the workings of the AI software are not understandable, it can create doubts in the minds of practitioners and compromise its clinical significance. Furthermore, the lack of interpretability and transparency can make it difficult to predict failures and generalize specific techniques for similar scenarios. Therefore, improving visualization and conducting thorough scientific research are critical to ensure that AI is effectively integrated into healthcare, providing customized care to patients based on their specific needs [38].

AI & Ethics

It is important to consider the potential risks and challenges associated with AI in healthcare. In addition to the ethical challenges, there are also concerns around data security and patient confidentiality, as well as the potential for AI to exacerbate existing healthcare disparities and biases if not properly designed and implemented. It is crucial that AI development in healthcare is done

in a responsible and ethical manner, with careful consideration of these issues and ongoing monitoring and evaluation of AI systems to ensure they are not causing harm [39].

AI & Future Scope

Overall, the future of AI in dentistry is promising. With the ability to improve diagnosis accuracy, assist in treatment planning, and enhance the precision of prosthetic design, AI has the potential to revolutionize the dental field. However, it is important to address ethical concerns, such as data privacy and algorithmic fairness, and for dental practitioners to have a fundamental understanding of AI technology to ensure its proper use. As AI-based services continue to join the market, dental practitioners should keep up to date with the latest developments to choose the right AI service and improve the patient experience [40].

CONCLUSION

AI has great potential to revolutionize the field of dentistry by improving diagnosis, treatment planning, prosthetic design, and patient experience. However, ethical concerns such as data privacy, informed consent, safety, transparency, and algorithmic fairness must be addressed to maximize the benefits of AI in healthcare. AI should be viewed as a tool that can assist dental surgeons in performing their jobs professionally, rather than as a replacement for human knowledge and expertise. As AI continues to evolve, it is important to prioritize human interests while improving its ability to handle large amounts of data. With careful design and long-term clinical validation, AI can be an unbiased, reproducible, user-friendly, and transparent auxiliary for dental surgeons. By utilizing AI in a multidisciplinary approach, researchers and practitioners can improve both oral and overall health outcomes for patients.

REFERENCES

1. Holzinger, A., Langs, G., Denk, H., Zatloukal, K., & Müller, H. (2019). Causability and explainability of artificial intelligence in medicine. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *9*(4), e1312.
2. Schwendicke, F., Singh, T., Lee, J. H., Gaudin, R., Chaurasia, A., Wiegand, T., ... & Krois, J. (2021). Artificial intelligence in dental research: Checklist for authors, reviewers, readers. *Journal of dentistry*, *107*, 103610.
3. Bindushree, V., Sameen, R. J., Vasudevan, V., Shrihari, T. G., Devaraju, D., & Mathew, N. S. (2020). Artificial intelligence: In modern dentistry. *Journal of Dental Research and Review*, *7*(1), 27.
4. Chen, Y. W., Stanley, K., & Att, W. (2020). Artificial intelligence in dentistry: current applications and future perspectives. *Quintessence Int*, *51*(3), 248-257.
5. Rekow, E. D. (2020). Digital dentistry: The new state of the art—Is it disruptive or destructive?. *Dental Materials*, *36*(1), 9-24.
6. Khanagar, S. B., Al-Ehaideb, A., Maganur, P. C., Vishwanathaiah, S., Patil, S., Baeshen, H. A., ... & Bhandi, S. (2021). Developments, application, and performance of artificial intelligence in dentistry–A systematic review. *Journal of dental sciences*, *16*(1), 508-522.
7. Ahmed, N., Abbasi, M. S., Zuberi, F., Qamar, W., Halim, M. S. B., Maqsood, A., & Alam, M. K. (2021). Artificial intelligence techniques: analysis, application, and outcome in dentistry—a systematic review. *BioMed research international*, *2021*, 9751564.
8. Farook, T. H., Jamayet, N. B., Abdullah, J. Y., & Alam, M. K. (2021). Machine learning and intelligent diagnostics in dental and orofacial pain management: A systematic review. *Pain Research and Management*, *2021*, 6659133.
9. Carlsson, G. E., & Omar, R. (2006). Trends in prosthodontics. *Medical Principles and Practice*, *15*(3), 167-179.
10. Becker, C. M., Kaiser, D. A., & Goldfogel, M. H. (1994). Evolution of removable partial denture design. *Journal of Prosthodontics*, *3*(3), 158-166.
11. Hsu, C. J. (2009). Stewart's Clinical Removable Partial Prosthodontics, 4th edition. Phoenix RD, Cagna DR, DeFreest CF (ed): Quintessence, Chicago.
12. Mijiritsky, E., Lorean, A., Mazor, Z., & Levin, L. (2015). Implant tooth-supported removable partial denture with at least 15-year long-term follow-up. *Clinical Implant Dentistry and Related Research*, *17*(5), 917-922.
13. Zhang, B., Dai, N., Tian, S., Yuan, F., & Yu, Q. (2019). The extraction method of tooth preparation margin line based on S-Octree CNN. *International Journal for Numerical Methods in Biomedical Engineering*, *35*(10), e3241.
14. Runte, C., Dirksen, D., Deleré, H., Thomas, C., Runte, B., Meyer, U., ... & Bollmann, F. (2002). Optical data acquisition for computer-assisted design of facial prostheses. *International Journal of prosthodontics*, *15*(2), 129-132.
15. Verdonck, H. W., Poukens, J., Overveld, H. V., & Riediger, D. (2003). Computer-assisted maxillofacial prosthodontics: a new treatment protocol. *International Journal of prosthodontics*, *16*(3), 326-328.
16. Jiao, T., Zhang, F., Huang, X., & Wang, C. (2004). Design and fabrication of auricular prostheses by CAD/CAM system. *International Journal of Prosthodontics*, *17*(4), 460-463.
17. Shen, K. L., Huang, C. L., Lin, Y. C., Du, J. K., Chen, F. L., Kabasawa, Y., ... & Huang, H. L. (2022). Effects of artificial intelligence-assisted dental monitoring intervention in patients with periodontitis: A randomized controlled trial. *Journal of Clinical Periodontology*, *49*(10), 988-998.
18. Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Pedagogy and innovative care tenets in

COVID-19 pandemic: An enhancive way through Dentistry 4.0. *Sensors International*, *2*, 100118.
19. Lahoud, P., Jacobs, R., Boisse, P., EzEldeen, M., Ducret, M., & Richert, R. (2022). Precision medicine using patient-specific modelling: State of the art and perspectives in dental practice. *Clinical Oral Investigations*, *26*(8), 5117-5128.
20. Shajahan, P. A., Raghavan, R., & Joe, N. (2021). Application of artificial intelligence in prosthodontics. *Int J Sci health care res*, *1*, 57-60.
21. Hadj Saïd, M., Le Roux, M. K., Catherine, J. H., & Lan, R. (2020). Development of an Artificial Intelligence Model to Identify a Dental Implant from a Radiograph. *International Journal of Oral & Maxillofacial Implants*, *35*(6), 1077-1082.
22. Lee, J. H., & Jeong, S. N. (2020). 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*, *99*(26), e20787.
23. Takahashi, T., Nozaki, K., Gonda, T., & Ikebe, K. (2021). A system for designing removable partial dentures using artificial intelligence. Part 1. Classification of partially edentulous arches using a convolutional neural network. *journal of prosthodontic research*, *65*(1), 115-118.
24. Lerner, H., Mouhyi, J., Admakin, O., & Mangano, F. (2020). 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*, *20*(1), 1-16.
25. Jivraj, S., & Chee, W. (2006). Rationale for dental implants. *British dental journal*, *200*(12), 661-665.
26. Alarifi, A., & AlZubi, A. A. (2018). Memetic search optimization along with genetic scale recurrent neural network for predictive rate of implant treatment. *Journal of Medical Systems*, *42*, 1-7.
27. Sahiwal, I. G., Woody, R. D., Benson, B. W., & Guillen, G. E. (2002). Radiographic identification of nonthreaded endoseous dental implants. *The Journal of prosthetic dentistry*, *87*(5), 552-562.
28. Michelinakis, G., Sharrock, A., & Barclay, C. W. (2006). Identification of dental implants through the use of Implant Recognition Software (IRS). *International dental journal*, *56*(4), 203-208.
29. Raith, S., Vogel, E. P., Anees, N., Keul, C., Güth, J. F., Edelhoff, D., & Fischer, H. (2017). Artificial Neural Networks as a powerful numerical tool to classify specific features of a tooth based on 3D scan data. *Computers in biology and medicine*, *80*, 65-76.
30. Jreige, C. S., Kimura, R. N., Segundo, Â. R. T. C., Coachman, C., & Sesma, N. (2022). Esthetic treatment planning with digital animation of the smile dynamics: A technique to create a 4-dimensional virtual patient. *The Journal of Prosthetic Dentistry*, *128*(2), 130-138.
31. Pareek, M., & Kaushik, B. (2022). Artificial intelligence in prosthodontics: a scoping review on current applications and future possibilities. *Int J Adv Med*, *9*, 367.
32. Alexander, B., & John, S. (2018). Artificial intelligence in dentistry: Current concepts and a peep into the future. *Int J Adv Res*, *6*(12), 1105-1108.
33. Grischke, J., Johannsmeier, L., Eich, L., Griga, L., & Haddadin, S. (2020). Dentronics: Towards robotics and artificial intelligence in dentistry. *Dental Materials*, *36*(6), 765-778.
34. Kirubarajan, A., Young, D., Khan, S., Crasto, N., Sobel, M., & Sussman, D. (2022). Artificial intelligence and surgical education: A systematic scoping review of interventions. *Journal of Surgical Education*, *79*(2), 500-515.
35. Mureşanu, S., Almăşan, O., Hedeşiu, M., Dioşan, L., Dinu, C., & Jacobs, R. (2022). Artificial intelligence models for clinical usage in dentistry with a focus on dentomaxillofacial CBCT: a systematic review. *Oral Radiology*, 39, 18-40.
36. Crompton, H., Jones, M. V., & Burke, D. (2022). Affordances and challenges of artificial intelligence in K-12 education: a systematic review. *Journal of Research on Technology in Education*, 1-21.
37. Mohammad-Rahimi, H., Nadimi, M., Rohban, M. H., Shamsoddin, E., Lee, V. Y., & Motamedian, S. R. (2021). Machine learning and orthodontics, current trends and the future opportunities: A scoping review. *American Journal of Orthodontics and Dentofacial Orthopedics*, *160*(2), 170-192.
38. Khanagar, S. B., Vishwanathaiah, S., Naik, S., Al-Kheraif, A. A., Divakar, D. D., Sarode, S. C., ... & Patil, S. (2021). Application and performance of artificial intelligence technology in forensic odontology–A systematic review. *Legal Medicine*, *48*, 101826.
39. Khanagar, S. B., Al-Ehaideb, A., Vishwanathaiah, S., Maganur, P. C., Patil, S., Naik, S., ... & Sarode, S. S. (2021). Scope and performance of artificial intelligence technology in orthodontic diagnosis, treatment planning, and clinical decision-making-a systematic review. *Journal of dental sciences*, *16*(1), 482-492.
40. Holzinger, A., Langs, G., Denk, H., Zatloukal, K., & Müller, H. (2019). Causability and explainability of artificial intelligence in medicine. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *9*(4), e1312.