REVIEW ARTICLE

International Journal of Dental Materials (ISSN: 2582-2209 (Online))
DOI: http://dx.doi.org/10.37983/IJDM.2025.7403

Artificial Intelligence–Driven Advancements in Dental Implants: A Narrative Review

Sowmiya Srinivasan[1], Sridharan Rajendran[1], Shiyam Sundhar Indirajith[1], Ida Esther Celina Jeyakumar[1], Leoney Antony[2,*]

[1] Department of Prosthodontics, Crown and Bridge, Chettinad Dental College and Research Institute, Chennai, Tamil Nadu, India.
[2] Department of Prosthodontics and Crown and Bridge, Government Dental College and Hospital, Cuddalore district, Chidambaram, Tamil Nadu, India.

Corresponding author:
Leoney Antony
Department of Prosthodontics and Crown and Bridge, Government Dental College and Hospital, Cuddalore district, Chidambaram, Tamil Nadu, India.
Email: antony.leoney@gmail.com

Article History
Received: 24th November 2025
Accepted: 28th December 2025
Published: 31st December 2025

Abstract

We are in the era of advancements with digital innovative technologies, which have taken dental systems to the next level through the discovery of artificial intelligence (AI). Recently, AI systems have gained significant popularity in the field of prosthodontics, particularly in implant dentistry. Various studies have emphasized the impact of AI on oral implants, particularly in terms of diagnostic efficiency, treatment planning ability, and subsequent patient outcomes, thereby highlighting the accuracy, rapidity, and precision of decision-making. AI continues to expand in future and promises to amend the view of implant dentistry and lead it to an efficient and personalized part of the oral healthcare system. This review mainly focuses on the advancements of AI-based research in dental implantology and also explores the various applications of AI models. Inclusive data from databases in PubMed, Scopus, Web of Science, and Google Scholar were thoroughly explored, and the role of AI in implant identification, planning, prediction, and complication management was described. Although there are a few drawbacks present, which make AI a challenging factor for continued use in clinical practice. Further research with numerous clinical trials can break through the limitations and be used as an excellent supportive tool.

Keywords: Artificial Intelligence (AI), Implant Dentistry, Diagnosis, Digital Dentistry.

Cite this article as: Sowmiya S, Sridharan R, Indirajith SS, Ida Esther Celina J, Leoney A. Artificial Intelligence–Driven Advancements in Dental Implants: A Narrative Review. **Int J Dent Mater. 2025;7(4):120-124.**

1. Introduction

In recent years, prosthodontics has undergone rapid technological evolution, with the integration of artificial intelligence (AI) and robotics significantly transforming clinical workflows [1,2]. These innovations have introduced a new era in implant dentistry by enhancing diagnostic accuracy, improving treatment planning, and supporting predictable patient outcomes [1,4]. The application of AI in implant dentistry demonstrates considerable potential in improving clinical efficiency, precision, and overall treatment success.

Artificial intelligence is defined as the branch of computer science concerned with the development of systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, and decision-making [1,3]. The concept of AI was formally introduced during the Dartmouth Conference in 1956, with foundational contributions by Alan Turing, who proposed the "Turing Test" to evaluate machine intelligence [2]. Major subfields of AI include artificial neural networks (ANNs), machine learning (ML), deep learning (DL), and robotics. Among these, ML and DL have gained substantial attention in dentistry due to their ability to analyse large datasets and identify complex patterns relevant to diagnosis, treatment planning, and outcome prediction [1,4].

The operational framework of AI models generally involves two fundamental phases: a training phase and a testing phase. During the training phase, large datasets are provided to the algorithm to enable learning of relevant features, patterns, and associations. The objective of this phase is to optimise the model's ability to make accurate predictions. In the testing phase, the trained model is evaluated using previously unseen data to assess its performance, reliability, and generalisability [2,5].

Artificial neural networks (ANNs) are computational models inspired by the structure of the human brain and consist of interconnected input, hidden, and output layers composed of artificial neurons [2,5]. Convolutional neural networks (CNNs), a specialised subset of ANNs, are particularly effective for image-based analysis and are widely employed in medical and dental imaging [6]. CNNs process visual data using convolutional operations and kernel filters that detect spatial features at multiple scales. Pooling layers further reduce computational complexity while preserving essential image characteristics, thereby improving classification and prediction accuracy [6]. In dentistry, CNN-based models are commonly applied to radiographic images such as periapical radiographs, panoramic radiographs, and cone-beam computed tomography (CBCT) scans [1,6,7].

Advancements in implantology have significantly improved dental rehabilitation by providing reliable solutions for single-tooth replacement, partial edentulism, and complete edentulism [7,8]. Numerous studies have reported enhanced implant survival rates, improved functional outcomes, and better patient quality of life. However, despite technological progress, challenges related to diagnosis, treatment planning, and long-term prognosis remain [9]. AI-based applications offer promising solutions to address these challenges by supporting clinicians in implant identification, planning, risk prediction, and complication management [1,4,6].

Therefore, this narrative review aimed to highlight the prevailing advancements in artificial intelligence within implant dentistry and to discuss its applications across various domains, including implant identification, treatment planning, outcome prediction, and complication management, along with associated advantages and limitations.

2. Potential benefits of applying AI in implant dentistry

The primary benefits of using artificial intelligence (AI) in implant dentistry for implant placement are boundless. In this way, AI models guide in identifying implant types by implant successive prediction, and design optimisation using combined finite element analysis calculations, thereby enhancing functionality and acceptance in the prosthodontics treatment procedure [2,10]. As AI reinforce this process through a predictive analytics system, which enables dentists to identify patterns through patient data and predict the treatment required. Hence, it helps in proactively addressing the potential issues of patients and provides more personalised treatment plans, according to the individual needs, thereby reducing the risk of complications and improving the overall success rates of dental implant placement [1,4,7].

Furthermore, human errors and restoration quality are enhanced by AI technology, which substantially improves the certainty of dental implant procedures. Also, it is faster and more efficient, reduces the time required for treatment and enables higher levels of personalised dental care, benefiting both patient and dentists. Nevertheless, further researches are needed to completely understand the potential benefits of applying and utilising AI in implant dentistry. Therefore, AI in implant placement holds significant promise for advancing the dental field. However, further research is required to fully understand and validate the potential benefits of applying AI in implant dentistry" [11].

3. AI in oral implant identification

Identification of implant design or pattern is vital for implant placement as well as sustenance and restoration of implants, which plays a major challenging factor for clinicians. In the previous literature, there are several methods that were recommended for implant identification, but are nonetheless neither quick nor easy, and also require human effort. Since AI techniques were implemented by researchers, they have proven to be beneficial in improving the accuracy and efficiency of implant identification. In the identification of oral implants, digital intraoral radiograph imaging is used to train the AI model. The given training data trains the algorithm, and the testing data analyses the trained AI model's performance. There are a few studies which used AI for implant identification.

Lee JH *et al.* (2020) studied the dental implants using 11,980 images of digital intraoral panoramic

and perapical radiographs with VGG-19 (Visual Geometry Group), GoogLeNet Inception-v3, ResNet-50, Automated deep CNN, Pre-trained and fine-tuned deep CNN architecture, algorithm architecture along with accuracy rate of 89.1% in VGC-19, 92.2% IN GoogLeNet Inception-v3, 90.7% in ResNet-50, 95.5% in Automated deep CNN and 97.1% in deep CNN [12]. Saïd M H *et al*. 2020 also studied the periapical and panoramic digital radiography with 1206 images using Pretrained GoogLeNet Inception with an accuracy of 93.8% [13]. Takahashi T *et al*. in 2020 studied the panoramic radiograph with 1282 images using YOLOv3 (you only look once) with an accuracy of 71% [14]. Also, Sukegawa S *et al*. (2021) identified using panoramic radiograph in 8859 images using Basic CNN, VGG16 transfer, VGG16 and 19 fine-tuning, VGG19 transfer with accuracy of 86% 89.9% 93.5% 88% and 92.7% [15]. Kim HS *et al*. (2022) studied using periapical radiographs in 801 images with algorithm architectures of SqueezeNet, GoogLeNet, ResNet-18 and 50, MobileNet-v2, with an average accuracy of 96% [16]. Kong H J *et al*. (2023) studied 28,112 panoramic images using the Ensemble technique applied to Efficient Net and Res 2 Next algorithms with 96% accuracy [17], and finally, Park W *et al*. (2023) studied in higher population of 156,965 digital periapical and panoramic images using an automated deep learning (DL) algorithm with 88.53% accuracy [18].

4. AI application in implant planning

Implant planning before the surgical procedure plays a vital role in long-term implant success and fewer surgical complications. Pre-surgically Cone-Beam Computed Tomography is considered an effective tool as it provides significant information on roots, bone and nerve morphologies and other pivotal anatomic structures, present also aids in locating the site, implant size and need for additional surgeries at the site of implant placement. However, with AI, it cannot be processed; also, manual delineation is required. Mandibular canal detection, tooth segmentation are some of the critical parts in implant planning and that exclusively should be operated manually. These can also be automated with deep learning, a subset of AI, but further validation with clinical trials is required in future for better implementation [2,4]. Applications in implant identification and planning are summerized in Table 1.

A study described the Automatic and simultaneous detection of alveolar bone and mandibular canal using the Dental-YOLO AI model with an accuracy rate of 99.46% [19]. Alsomali M *et al*. (2022) studied the localisation of the position of radiographic stent GP markers automatically using CBCT images to recognise proposed implant positions, by DL models with 83% accuracy [20]. Sakai T *et al*. (2023) studied using LeNet-5, and analysed the AI model to identify the appropriate implant drilling protocol utilising CBCT images with 93.8% accuracy [21].

5. AI-guided prediction in dental implantology

In spite of extensive technologies and advancements evolved in implant placement, a diagnostic and planning protocol, some complications remain significantly concerning. One such complication frequently observed in implants is peri-implantitis, which leads to subsequent bone loss eventually, implant failure occurs. Effective and periodic diagnosis and maintenance can provide preventive care. AI systems in such a way considerably detect and predict peri-implantitis and can be a valuable adjunct for effective treatment strategies to prevent and manage peri-implantitis. Various studies have investigated the management of peri-implantitis. A study evaluated the extent of periodontal damage around dental implants in periapical film using a CNN model and achieved an accuracy of 90.45% [10]. Various other studies evaluated the prediction of dental implants guided by AI [22,23]. Oh S *et al*. (2023), Prediction of osseointegration from radiographs using ResNet-18, 34, 50, DenseNet-121,201, MobileNet-V2, and MobileNet-V3 with an overall 80% accuracy [24]. Ramachandran RA *et al*. (2023) evaluated the early detection and prediction of bio-tribocorrosion in dental implant materials using Logistic Regression, Latent Dirichlet Allocation, k-NN, Decision Tree, Support Vector Classifier, and Random Forest Models with an overall 90% accuracy rate [25]. Park J H *et al*. in 2023 classified dental implant size using periapical radiographs using VGG16 Cluster analysis with 99% accuracy [26].

6. Challenges and prospects

Regardless of the extensive benefits of advanced technologies, there are still some challenges that exist. Importantly, due to its high cost, it is not affordable in all health care centres, and also not all people can benefit. As it is in the developing era, it requires time to master the techniques by surgeons as well as to train the AI models. Therefore, it is essential to utilize the technique with continuous

Table 1. Summary of AI applications in implant identification and planning.

Author (Year)	Study Objective	AI Model Used	Key Findings
Lee JH *et al.* (2020) [12]	Identification of dental implant systems from radiographs	VGG-19, GoogLeNet Inception-v3, ResNet-50, Deep CNN	Maximum accuracy of 97.1%
Saïd MH *et al.* (2020) [13]	Implant identification using radiographs	GoogLeNet Inception	Accuracy of 93.8%
Takahashi T *et al.* (2020) [14]	Automated implant identification	YOLOv3	Accuracy of 71%
Sukegawa S *et al.* (2021) [15]	Classification of implant systems	VGG16, VGG19	Accuracy up to 93.5%
Saïd MH *et al.* (2020) [13]	Implant identification using radiographs	GoogLeNet Inception	Accuracy of 93.8%
Takahashi T *et al.* (2020) [14]	Automated implant identification	YOLOv3	Accuracy of 71%
Sukegawa S *et al.* (2021) [15]	Classification of implant systems	VGG16, VGG19	Accuracy up to 93.5%
Saïd MH *et al.* (2020) [13]	Implant identification using radiographs	GoogLeNet Inception	Accuracy of 93.8%

improvement of the AI [4,5]. Very importantly, dentists must maintain their clinical judgment and make sure that technology is used as an auxiliary tool rather than replacing their professional judgment, also some ethical considerations, such as maintaining the patient's data in a secure manner and patients' privacy. Thereby, training the AI system to perform more complicated tasks independently under the guidance of human surgeons in the near future and analyzing the multi-model patient data, anatomical variations and scrutinizing the ethical considerations can provide a guaranteed success in future [1,6].

7. Conclusion

It can be concluded that the integration of artificial intelligence in implant dentistry effectively increases the clinical outcomes by proper decision planning, patient satisfaction, and excellent procedural competency. Thereby, holds a promising future, upon which continuous research is widespread with effective endorsement. However, it is highlighted that AI cannot replace clinicians completely; instead, it can provide support for clinicians. Some clinicians adopting roles utilise special human skills such as empathy, motivation, and comprehensive assimilation as part of an integrated patient care. Hence, further research with various organised data sets and clinical trials can make the successive changes across the modern globe.

Conflicts of interest: The Authors declared no conflicts of interest.

Financial support: None

References

1. Altalhi AM, Alharbi FS, Alhodaithy MA, Almarshedy BS, Al-Saaib MY, Aljohani AS, Alshareef AH, Muhayya M, AL-harbi NH. The Impact of Artificial Intelligence on Dental Implantology: A Narrative Review. Cureus. 2023;15(10):e47941. https://doi.org/10.7759/cureus.47941
2. Revilla-León M, Gómez-Polo M, Vyas S, Barmak BA, Galluci GO, Att W, Krishnamurthy VR. Artificial intelligence applications in implant dentistry: A systematic review. J Prosthet Dent. 2023;129(2):293-300. https://doi.org/10.1016/j.prosdent.2021.05.008
3. Saeed A, Alkhurays M, AlMutlaqah M, AlAzbah M, Alajlan SA. Future of using robotic and artificial intelligence in implant dentistry. Cureus. 2023;15(8):e43209. https://doi.org/10.7759/cureus.43209
4. Khan SF, Siddique A, Khan AM, Shetty B, Fazal I. Artificial intelligence in periodontology and implantology—a narrative review. J Med Artif Intelligen. 2024;7:6. https://doi.org/10.21037/jmai-23-186
5. Duggal N. What is Artificial Intelligence and Why It Matters in 2024? 2023. https://softcircles.com/blog/what-is-artificial-intelligence-and-why-it-matters-in-2024 Accessed 6.12.2024.
6. Ramani S, Vijayalakshmi R, Mahendra J, NalinaKumari CB, Ravi N. Artificial intelligence in periodontics–An overview. IP Int J Periodontol Implantol. 2023;8(2):71-4. https://doi.org/10.18231/j.ijpi.2023.015
7. Benakatti V, Nayakar RP, Patil S. Artificial intelligence applications in dental implantology: A narrative review. IP Annals Prosthodont Restorat Dent. 2024;10(2):118-23. https://doi.org/10.18231/j.aprd.2024.023
8. Shan T, Tay FR, Gu L. Application of artificial intelligence in Dentistry. J Dent Res. 2021;100(3):232–44. https://doi.org/10.1177/0022034520969115
9. Rutkowski JL. Artificial Intelligence (AI) Role in Implant Dentistry. J Oral Implantol. 2024;50(1):1-2. https://doi.org/10.1563/Editorial
10. Tandon D, Rajawat J, Banerjee M. Present and future of artificial intelligence in dentistry. J Oral Biol Craniofac Res. 2020;10(4):391-6. https://doi.org/10.1016/j.jobcr.2020.07.015
11. Geng, H. et al. Application of artificial intelligence in implant planning, placement, and prosthesis manufacturing: A systematic review. J Prosthodont, 2019;28(7);759-766.
12. Lee JH, Kim YT, Lee JB, Jeong SN. A Performance Comparison between Automated Deep Learning and Dental Professionals in Classification of Dental Implant Systems from Dental Imaging: A Multi-Center Study. Diagnostics (Basel). 2020;10(11):910. https://doi.org/10.3390/diagnostics10110910
13. Saïd MH, Roux MKL, Catherine JH, Lan R. Development of an artificial intelligence model to identify a dental implant from a radiograph. Int J Oral Maxillofac Implants. 2020;36(6): 1077–82. https://doi.org/10.11607/jomi.8060
14. Takahashi T, Nozaki K, Gonda T, Mameno T, Wada M, Ikebe K, et al. Identification of dental implants using deep learning - pilot study. Int J Implant Dent. 2020;6:53–9. https://doi.org/10.1186/s40729-020-00250-6
15. S, Yoshii K, Hara T, Yamashita K, Nakano K, Yamamoto N, et al. Deep Neural Networks for Dental Implant System Classification. Biomolecules.2020;10(7):984. https://doi.org/10.3390/biom10070984
16. Kim JE, Nam NE, Shim JS, Jung YH, Cho BH, Hwang JJ, et al. Transfer Learning via Deep Neural Networks for Implant

Fixture System Classification Using Periapical Radiographs. J Clin Med. 2020;9(4):1117. https://doi.org/10.3390/jcm9041117
17. Kong HJ, Eom SH, Yoo JY, Lee JH. Identification of 130 dental implant types using ensemble deep learning. Int J Oral Maxillofac Implants. 2023;38(1):150–6. https://doi.org/10.11607/jomi.9818
18. Park W, Huh JK, Lee JH. Automated deep learning for classification of dental implant radiographs using a large multi-center dataset. Sci Rep. 2023;13(1):4862. https://doi.org/10.1038/s41598-023-32118-1
19. Mangano FG, Admakin O, Lerner H, Mangano C. Artificial intelligence and augmented reality for guided implant surgery planning: A proof of concept. J Dent. 2023;133:104485. https://doi.org/10.1016/j.jdent.2023.104485
20. Alsomali M, Alghamdi S, Alotaibi S, Alfadda S, Altwaijry N, Alturaiki I, et al. Development of a deep learning model for automatic localization of radiographic markers of proposed dental implant site locations. Saudi Dent J. 2022;34(3):220–5. https://doi.org/10.1016/j.sdentj.2022.01.002
21. Sakai T, Li H, Shimada T, Kita S, Iida M, Lee C, et al. Development of artificial intelligence model for supporting implant drilling protocol decision making. J Prosthodont Res. 2023;67(3):360–5. https://doi.org/10.2186/jpr.JPR_D_22_00053
22. Oliveira ALI, Baldisserotto C, Baldisserotto J. A Comparative Study on SVM and Constructive RBF Neural Network for Prediction of Success of Dental Implants. In: Sanfeliu A, Cortés ML, editors. Progress in Pattern Recognition, Image Analysis and Applications. CIARP . vol. 3773. Berlin, Heidelberg: Springer; 2005. https://doi.org/10.1007/11578079_104
23. Moayeri RS, Khalili M, Nazari M. A hybrid method to predict success of dental implants. Int J Adv Comput Sci Appl. 2016;7(5):1–6. https://doi.org/10.14569/IJACSA.2016.070501
24. Oh S, Kim YJ, Kim J, Jung JH, Lim HJ, Kim BC, et al. Deep learningbased prediction of osseointegration for dental implant using plain radiography. BMC Oral Health. 2023;23(1):208. https://doi.org/10.1186/s12903-023-02921-3
25. Ramachandran RA, Barão VVR, Ozevin D, Sukotjo C, Pai S, MathewM, et al. Early predicting tribocorrosion rate of dental implant titanium materials using random forest machine learning models. Tribol Int. 2023;187:108735. https://doi.org/10.1016/j.triboint.2023.108735.
26. Park J, Moon H, Jung H, Hwang J, Choi Y, Kim JE, et al. Deep learning and clustering approaches for dental implant size classification based on periapical radiographs. Sci Rep. 2023;13:16856. https://doi.org/10.1038/s41598-023-42385-7