Misr Dental Science and Research Journal

Online ISSN: 297-315X

Smarter Smiles: The Integration of Artificial Intelligence in Fixed Prosthodontics: A Narrative Review

FIXED PROSTHODONTIC

Vol. 2, July, 2025

Hend Ashraf Abdel Hadi[1]

DOI: 10.21608/mdsrj.2025.443703

Abstract

Artificial Intelligence (AI) is rapidly transforming the field of dentistry, particularly in fixed prosthodontics. With capabilities ranging from diagnosis and treatment planning to digital impressions and prosthesis design, as well as outcome prediction, AI enhances accuracy, efficiency, and patient satisfaction. This narrative review explores the applications, benefits, challenges, and future potential of AI in fixed prosthodontics, highlighting current technologies such as machine learning, neural networks, and computer vision, and their integration with digital workflows, including CAD/CAM and intraoral scanning. Despite its transformative promise, AI adoption faces limitations related to data quality, clinical validation, and ethical concerns. This review highlights the significance of education and regulatory frameworks in facilitating the safe and effective deployment of AI in prosthodontic practice.

Keywords: Artificial Intelligence, Fixed Prosthodontics, CAD/CAM, Machine Learning, Digital Workflow.

[1] Assistant lecturer, College of Oral and Dental Surgery, Misr University for Science and Technology.

Introduction

Fixed prosthodontics has historically relied on manual dexterity, clinician expertise, and mechanical precision to achieve functional and esthetic dental restorations. However, with the increasing complexity of patient expectations and advancements in digital technologies, the field is undergoing significant transformation. One of the most impactful developments is the integration of Artificial Intelligence (AI), a domain of computer science that mimics human cognition, including learning, reasoning, and decision-making [(1)].

AI has gained substantial traction in dentistry, particularly in areas such as diagnostic imaging, prosthetic design, treatment planning, and patient-specific care. It supports clinical decision-making by processing large volumes of health data, analyzing treatment protocols, and generating evidence-based recommendations tailored to individual patients [(2,3)]. Furthermore, AI-powered tools are being used to simulate virtual patients, offering innovative platforms for training in medical history taking, recordkeeping, and clinical communication [(4)].

In the context of fixed prosthodontics, AI is driving innovation through its integration with digital workflows, including computer-aided design/computer-aided manufacturing (CAD/CAM), 3D printing, and intraoral scanning. These technologies enable the fabrication of restorations with enhanced accuracy, fit, and esthetics [(5,6)]. Additionally, AI-based systems, including reactive machines, are being deployed for tasks such as automated detection of dental pathology, generation of 3D anatomical models, and prosthetic design, thereby enhancing both clinical outcomes and operational efficiency [(7)].

Moreover, augmented reality (AR) and virtual reality (VR) interfaces, often augmented by AI algorithms, are improving dental education and patient engagement by enabling real-time visualization of treatment outcomes and complex procedures [(7)]. These technologies not only contribute to better diagnostics and planning but also support patient-centered care by fostering clearer communication and shared decision-making.

This narrative review aims to explore the foundational principles, clinical applications, and emerging trends of AI in fixed prosthodontics. It discusses current AI methodologies, such as machine learning, deep learning, and computer vision, and evaluates their role in shaping diagnostic accuracy, prosthesis design, treatment simulation, and personalized care delivery.

Foundations of AI in Dentistry

Machine Learning (ML)

Machine Learning (ML), a subset of artificial intelligence, enables computer systems to learn from data and enhance their performance without explicit programming for each task. By utilizing algorithms trained on either labeled data (supervised learning) or unlabeled data (unsupervised learning), ML identifies patterns and generates predictive models. In dentistry, ML has been applied to various diagnostic and prognostic tasks, including the detection of dental caries from bitewing and periapical radiographs, classification of periodontal disease severity based on clinical and radiographic parameters, and prediction of outcomes such as tooth loss, implant failure, or orthodontic relapse using patient history and imaging data [8].

Deep Learning (DL)

Deep Learning (DL), a specialized branch of machine learning, utilizes multi-layered neural networks designed to simulate the way the human brain processes information, making it highly effective for complex pattern recognition tasks such as image and speech analysis. DL models extract hierarchical features from large datasets, progressing from basic visual elements like pixels and edges to more complex structures, such as entire tooth anatomy. These systems typically require extensive datasets and substantial computational power. In dentistry, deep learning has been successfully applied to automate tasks including tooth numbering and segmentation in panoramic radiographs, cephalometric landmark detection in orthodontic assessments, identification of apical lesions, cysts, and tumors in CBCT or panoramic imaging, and margin detection for crown preparation within CAD/CAM workflows [9].

Natural Language Processing (NLP)

Natural Language Processing (NLP) enables computers to understand, interpret, and generate human language, whether spoken or written. It works by using algorithms that tokenize text, analyze grammar and meaning, and identify relationships within language. In dentistry, NLP is applied to analyze clinical notes for diagnoses and treatment planning, power automated appointment systems through chatbots, convert spoken clinical instructions into text, and detect patterns in large dental datasets to support research or flag risks such as high caries incidence [10].

Computer Vision

Computer Vision, a branch of artificial intelligence, enables machines to interpret and process visual data such as images and videos. By leveraging deep learning or machine learning techniques, it analyzes images at the pixel level to identify features like shapes, edges, and densities. In dentistry, computer vision is increasingly utilized for tasks such as detecting bone loss in periodontitis from radiographs, identifying dental anomalies like supernumerary teeth or impacted canines, enhancing intraoral images automatically, and extracting precise quantitative measurements, including crown-to-root ratios and pulp volumes [11].

Applications of AI in Fixed Prosthodontics

Diagnosis and Case Selection

Artificial intelligence (AI) plays a pivotal role in enhancing diagnostic accuracy within the field of prosthodontics, where timely and precise diagnosis forms the foundation of effective treatment planning. The advent of advanced three-dimensional imaging and scanning technologies has led to a significant increase in data generation, necessitating efficient analytical tools. AI demonstrates a unique capacity to process and interpret vast datasets, extracting clinically relevant information to facilitate optimal diagnosis. This capability supports early disease detection, streamlines dental workflows, improves time efficiency, and reduces labor costs [12]. Furthermore, AI contributes to personalized treatment by aiding in the selection of appropriate prosthetic rehabilitation strategies, including the design, type (removable or fixed), and component selection of prostheses [13]. It can detect complex patterns and diagnostic indicators that may be difficult or time-consuming for clinicians to recognize [14]. Notably, AI systems have achieved diagnostic accuracies of up to 90% for periodontally compromised premolars and 95% for molars, underscoring their value in establishing evidence-based treatment protocols and enhancing overall prosthodontic outcomes [15].

Digital Smile Design (DSD)

Since its inception in 2012, Digital Smile Design (DSD) has evolved significantly from basic PowerPoint templates and photographic protocols to advanced digital platforms, with over 15 specialized software programs now available [16]. Smile design has become a prominent aspect of contemporary dentistry, aiming to harmonize dental aesthetics, including tooth alignment, shape, and color, with facial features to achieve optimal outcomes. This integrative approach bridges prosthodontics and aesthetic dentistry, which, though not a formally recognized specialty, requires a multidisciplinary strategy encompassing restorative, periodontal, orthodontic, and surgical procedures [17,18].

The incorporation of artificial intelligence (AI) into smile design represents a transformative shift, enabling precise analysis of facial characteristics such as symmetry, lip line, and tooth morphology to create personalized and functionally effective treatment plans [19]. AI-based systems, like the VisagiSMile concept, employ machine learning to correlate facial features with perceived personality traits, further refining treatment individualization [19]. Studies by Ceylan G. et al. and Deshmukh K. et al. have shown that AI-generated smile designs can be as aesthetically acceptable as those created by clinicians, especially in symmetrical cases, highlighting time efficiency and patient satisfaction [19,20].

The integration of AI facilitates a fully digital DSD workflow, traditionally regarded as technically demanding, and is increasingly applied in prosthodontic and aesthetic practices. Tools such as Smile Cloud 2.0 and Rubicon (2020) have gained traction across specialties, with innovations like Smile Cloud Biometrics, developed in 2023 by a Romanian team, providing a cloud-based platform for DSD, planning, and communication [21,22]. This system allows clinicians to upload patient data, receive AI-driven smile proposals, and generate STL files for mock-ups and guides, offering customizable and photorealistic simulations of future smiles [16,23].

A Romanian observational study involving 250 participants revealed differing aesthetic perceptions among patients, technicians, dentists, and students, emphasizing the value of interdisciplinary platforms like SmileCloud in aligning expectations and improving prosthetic outcomes [24]. These platforms also offer enhanced remote communication and streamlined workflows, utilizing intraoral scanners to replace traditional impressions and improve patient comfort [25]. Despite these advancements, ethical concerns persist regarding AI's use in smile design, including data privacy, transparency, and system accountability. In response, international guidelines have been established to ensure ethical and responsible integration of AI into dental practice [26].

CAD/CAM Integration

The delivery of high-quality fixed prostheses remains a central objective in prosthodontics. The integration of computer-aided design and computer-aided manufacturing (CAD/CAM) systems, along with a comprehensive three-dimensional digital workflow, has significantly transformed dental practice. Typically, an intraoral scan is acquired and transmitted to CAD/CAM software, which facilitates the design and fabrication through printing or milling of various prosthetic restorations such as inlays, onlays, crowns, and bridges [27,28].

This digital approach enhances clinical efficiency by reducing chairside time, conserving resources, and minimizing operator fatigue, while also decreasing the likelihood of human error in prosthesis fabrication [29,30].

The incorporation of artificial intelligence (AI) into CAD/CAM workflows has further optimized prosthetic outcomes. AI algorithms assist in accurately detecting and labeling crown preparation margins, enabling greater precision in prosthesis design [31]. In addition, AI is capable of processing large datasets to assess facial proportions, skin tone, ethnicity, anthropometric data, and patient expectations, thereby enhancing the aesthetic customization of prostheses [32].

It also plays a critical role in generating anatomically harmonious crown morphologies that are functionally compatible with opposing dentition [33]. Errors commonly associated with crown cementation—such as positional misalignment, occlusal discrepancies, and subgingival margin inaccuracies—can be mitigated through AI-based models, which facilitate better identification of preparation margins and help maintain interproximal and occlusal integrity [34]. Whether through additive manufacturing or subtractive milling, the collaboration between AI and CAD/CAM technologies has markedly improved prosthesis quality and precision, while streamlining laboratory workflows and reducing turnaround times for final prosthesis delivery [35].

AI-driven Tooth Preparation and Precision Finish Line Mapping

In 2024, Perceptive, a Boston-based company, introduced an AI-powered robotic system specifically designed for dental procedures, including the preparation of teeth for crowns. This innovative system employs advanced optical coherence tomography (OCT) alongside AI algorithms to generate detailed 3D tooth maps, which are subsequently analyzed to plan precise tooth preparations. Remarkably, procedures that traditionally require several hours can now be completed in approximately 15 minutes using this technology [(22,36)]. Additional advantages include enhanced precision and accuracy, resulting in improved crown and bridge fit, as well as greater consistency and reliability, since robotic systems are unaffected by fatigue or human error [(22)]. Although currently in the prototype phase, this technology has undergone successful testing in the United States and is expected to expand internationally, particularly in underserved regions where access to dental care is limited [(36)].

Another notable advancement in AI-driven dental robotics is Yomi by Neocis, introduced in 2017 as the first and only FDA-cleared robotic system for dental surgery. Primarily used for implant procedures, its underlying technology shows potential for adaptation to other treatments, including tooth preparation [(37)]. This was followed by the launch of DentSim by Image Navigation in 2018, an advanced AI-based dental training simulator using augmented reality to assist dental students in practicing procedures [(22)]. Although not used on patients, DentSim signifies a major step forward in integrating AI and robotics into dental education. Similarly, Tactile Robotics introduced a robotic system in 2019 that utilizes haptic feedback and AI to support dentists in performing accurate and efficient procedures, including tooth preparation [(22)].

Despite the limited number of fully developed AI-driven robotic systems currently available, their emergence represents a significant breakthrough in the fusion of AI and robotics within prosthodontics. These technologies are designed to increase clinical efficiency, procedural accuracy, and treatment outcomes [(22)]. While there is no current evidence of such robotic systems being implemented in Romania, their demonstrated effectiveness suggests a high likelihood of future global adoption, especially in countries facing barriers to conventional dental care.

The application of AI in mapping the preparation finishing line in fixed prosthodontics has demonstrated remarkable advancements in precision and efficiency over the past decade. Machine learning (ML) and deep learning (DL)-based algorithms have been developed to accurately detect and delineate preparation margins by analyzing digital impressions or intraoral scans, ensuring a precise fit for crowns and bridges [38]. These systems often utilize convolutional neural networks (CNNs) and other advanced AI architectures trained on extensive datasets of dental imagery [26].

In this regard, Zhang B. et al. proposed a CNN-based AI model utilizing the S-Octree structure to autonomously detect preparation finishing lines. Their study employed 380 digitized premolar and molar tooth preparation dies—processed as sparse point clouds and manually annotated—to train the model. The AI system demonstrated high accuracy in margin detection, achieving a success rate ranging from 90.6% to 97.4%. These findings underscore the potential of automating the identification of preparation margins and suggest a promising direction for integrating AI into CAD software for dental restoration design [39].

Beyond design automation, AI-driven tools provide real-time support to clinicians by assessing preparation quality and recommending modifications when necessary. This real-time assistance contributes to optimized outcomes and improved patient care [40]. Currently, such tools are being employed in clinical settings worldwide. In the United States, AI technologies are widely adopted in dental practices for real-time mapping of tooth preparations [41]. European countries like Germany and the United Kingdom have implemented AI tools extensively within dental research institutions and clinical settings [42]. In Asia, dental schools and clinics in China are actively developing and applying AI models for preparation mapping [43], while Japan and South Korea continue to lead in incorporating AI into advanced dental procedures [44].

Despite these developments, comparative studies between traditional and AI-assisted marginal preparation techniques remain limited. Notably, Mugri M.H. et al. [45] examined the influence of digital manufacturing methods (subtractive versus additive), preparation taper, and finish line design on the marginal adaptation of temporary crowns. Their findings highlight the crucial role of AI-integrated CAD/CAM systems in enhancing the accuracy of marginal fit.

Tooth Shade Selection

Tooth shade selection (TSS) in clinical prosthodontics has seen substantial technological advancement, with a wide range of tools now available to improve accuracy and reproducibility. Alongside traditional systems such as the Vita Classical Shade Guide and the Vita 3D-Master Shade Guide (VITA Zahnfabrik H. Rauter GmbH & Co., Bad Säckingen, Germany), modern methods include shade-matching spectrophotometers, intraoral electronic devices like the Vita Easyshade, the ShadeEye NCC Chroma Meter (Shofu Dental, Menlo, CA, USA), the iTero Element (Align Technology, Inc., San Jose, CA, USA), as well as colorimetric systems, hybrid devices, computer-aided shade selection software, and mobile applications (46).

In recent years, artificial intelligence (AI) has emerged as a transformative force in this domain, offering enhanced precision, objectivity, and standardization in TSS—an essential component of aesthetic success in fixed prosthodontics. Traditional methods often depend on visual comparison, which is inherently subjective and prone to inconsistency. In contrast, AI-based technologies have shown the potential to reduce human error and improve the reliability and efficiency of shade matching (40,47). Various branches of AI, including machine learning (ML), deep learning (DL), and convolutional neural networks (CNNs), have been increasingly integrated into shade selection protocols (48).

Machine learning algorithms have played a pivotal role in refining the accuracy of TSS. By analyzing large datasets comprising tooth images and corresponding shades, these algorithms learn to predict the appropriate shade based on image-based and contextual features (49). Notable techniques such as support vector machines (SVMs) and k-nearest neighbors (k-NN)—both supervised learning models—have been employed to classify tooth shades effectively (50). A study by Lee et al. (51) demonstrated the use of SVMs to accurately predict tooth shades through the analysis of colorimetric data from digital images. This approach offers a significant advantage over traditional visual methods by minimizing subjective bias and improving consistency.

In addition to ML approaches, DL models—particularly CNNs—have achieved promising results in TSS. Takahashi et al. (52) reported success using a CNN-based model to automate the shade-matching process. Trained on a large dataset of tooth images, their CNN system was able to detect subtle color variations that often escape human perception, leading to more precise and visually appealing restorations.

Further innovations have applied CNNs to analyze intraoral photographs and match them with appropriate shade of guide values. For instance, Mehta et al. [53] developed a CNN-based system trained on a diverse dataset that demonstrated superior performance in both speed and accuracy when compared to conventional methods. The model effectively accommodated variations in lighting conditions and patient demographics, highlighting its adaptability in clinical practice. This integration of AI into the shade selection process not only enhances the accuracy of restorations but also streamlines workflow, improving clinical efficiency in prosthodontic procedures.

Dental Patient Robot and AI in Dental Education

The dental patient robot is designed to simulate a wide range of natural human reactions, including blinking, sneezing, coughing, head shaking, eye rolling, and tongue movements. Notably, it can mimic signs of fatigue by holding its mouth open and can reproduce the human-like gag reflex, offering a highly realistic training experience for dental students. Such simulation capabilities make it a valuable tool for both undergraduate and postgraduate education. Artificial intelligence (AI) further enhances dental training by supporting the teaching of diagnostic skills, treatment planning, and procedural execution. Virtual AI-powered simulators provide a safe and controlled environment where students can practice clinical techniques before working with actual patients. These systems also enable personalized learning by adapting content and difficulty levels to each student's performance and needs. Additionally, AI can be employed in assessment and grading, delivering objective, consistent evaluations of students' clinical competencies and theoretical knowledge [54].

Challenges and Limitations

Despite the significant advancements AI has brought to prosthodontics, several limitations and ethical considerations remain. Concerns have been raised regarding patient confidentiality, data privacy, and the ethical implications of AI-generated diagnoses or treatment plans. Moreover, AI systems may inadvertently incorporate algorithmic biases, leading to discriminatory or suboptimal outcomes. The increasing automation of tasks traditionally performed by dental technicians also raises concerns about job displacement. To mitigate these issues, it is essential that dental professionals remain aware of the inherent limitations of AI and actively ensure the use of high-quality, unbiased data. Regular monitoring and updates of AI algorithms are necessary, along with the development and enforcement of ethical guidelines to guarantee the responsible and equitable implementation of AI in clinical practice [(55)].

A critical aspect of advancing AI in dentistry involves standardizing data collection and reporting methodologies. The development of a comprehensive, open-access dataset, including complete clinical, experimental, and therapeutic data, would significantly support the next phase of AI research. Such a dataset would facilitate the comparison of different algorithms and foster the development of more robust and accurate models, ultimately improving patient outcomes. As dental practices increasingly adopt digital tools such as electronic health records and imaging systems, the volume of data available for AI training will continue to grow. This expansion highlights the importance of a robust data infrastructure and standardized protocols to facilitate AI development and integration within dental care systems [(56)].

The advent of quantum computing holds promises for further enhancing AI applications, particularly in processing complex and large-scale datasets. Unlike classical computers that operate using binary digits (bits), quantum computers use qubits capable of existing in multiple states simultaneously. This capability allows for faster and more efficient data processing, which could significantly benefit machine learning and data modeling tasks in dental AI. However, quantum computing remains in the experimental phase, and considerable research is still needed to develop scalable and practical quantum systems for use in dentistry and other healthcare domains [(57)].

Interpretability remains a cornerstone of AI's integration into healthcare, including dentistry. Clinicians must be able to understand the reasoning behind AI-generated recommendations to build trust and ensure clinical relevance. A lack of transparency or explainability can lead to uncertainty, reduced adoption, and challenges in generalizing AI methods to varied clinical scenarios. Therefore, efforts to improve model visualization, interpretability, and scientific validation are essential to ensure that AI supports personalized, patient-centered care (58).

Beyond technical limitations, the ethical dimensions of AI in healthcare must be thoroughly considered. Alongside data privacy and security concerns, there is a risk that AI could unintentionally reinforce existing healthcare disparities if its development is not approached with inclusivity and fairness. These risks underscore the necessity for responsible AI development, which includes transparent design processes, continuous system evaluation, and ethical oversight to prevent unintended harm and ensure equitable healthcare delivery (59).

AI & Future Scope

The integration of artificial intelligence into dentistry offers significant opportunities to advance patient care by enhancing diagnostic precision, streamlining treatment planning, and increasing the accuracy and efficiency of prosthetic design (60). As AI tools become increasingly available in clinical practice, dental professionals must develop a solid understanding of their capabilities and limitations. Ethical considerations, such as data privacy, security, transparency, and fairness, must be addressed to ensure responsible use.

While AI can support clinical decision-making and optimize workflows, it should be viewed as an adjunct to, rather than a replacement for, human expertise. Its role lies in automating repetitive tasks and analyzing complex data to support personalized, evidence-based care. To fully realize its benefits, the deployment of AI must be guided by ethical standards, high-quality data, and ongoing validation through clinical research. When thoughtfully integrated, AI can serve as a dependable and transparent tool, helping dental professionals deliver more effective and patient-centered outcomes (61).

Conclusion

Artificial intelligence (AI) presents transformative potential in dentistry, particularly in enhancing diagnostic accuracy, treatment planning, prosthetic design, and overall patient care. To fully realize these benefits, it is essential to address key ethical considerations, including data privacy, informed consent, transparency, safety, and algorithmic fairness. Rather than replacing clinical expertise, AI should be regarded as an adjunctive tool that augments the capabilities of dental professionals. As AI systems become increasingly sophisticated, development must remain focused on serving human interests, ensuring systems are interpretable, secure, and aligned with clinical needs.

With rigorous design, thorough clinical validation, and ethical oversight, AI can become a reliable, reproducible, and user-friendly support system for dental practitioners. The integration of AI through a multidisciplinary approach—bringing together clinicians, researchers, engineers, and regulatory bodies—can significantly improve oral and systemic health outcomes. In fixed prosthodontics, AI is redefining standards by introducing new levels of precision, customization, and workflow efficiency. However, its successful implementation in daily practice hinges on continued innovation, robust collaboration, and a strong commitment to maintaining patient safety and trust.

References

1. Buchanan BG. A (very) brief history of artificial intelligence. AI Mag. 2004;25(4):53–60.
2. Mirghani I, Mufid A, Mohamed A. Artificial intelligence in dentistry: Current applications and future perspectives. J Oral Health Dent Res. 2016;7(2):65–72.
3. Shick RA, van Noort R, Wismeijer D. 3D printing technologies in digital dentistry. Br Dent J. 2019;227(11):819–25.
4. Cook DA, Erwin PJ, Triola MM. Computerized virtual patients in health professions education: A systematic review and meta-analysis. Acad Med. 2010;85(10):1589–1602.
5. Ting-shu S, Jian S. Intraoral digital impression technique: A review. J Prosthodont. 2014;23(4):291–5.
6. Bidra AS, Taylor TD, Agar JR. Computer-aided technology for fabricating complete dentures: Systematic review of historical background, current status, and future perspectives. J Prosthet Dent. 2013;109(6):361–6.
7. Joda T, Gallucci GO, Wismeijer D, Zitzmann NU, Zembic A. Augmented and virtual reality in dental medicine: A systematic review. Comput Biol Med. 2019; 108:93–100.
8. Schwendicke F, Krois J, et al. (2021). Machine learning in dentistry: current applications and future perspectives. Journal of Dentistry, 104:103849.
9. Lee JH, Kim DH, Jeong SN. (2022). Deep learning for tooth detection and classification. Journal of Dentistry, 119:104070.
10. Chen H, et al. (2020). Natural language processing in electronic dental records. J Med Syst, 44(2):32.
11. Kunz D, et al. (2020). Artificial intelligence in orthodontics: cephalometric landmark detection. Journal of Dentistry, 99:103376.
12. Paschou T, et al. Artificial intelligence in marketing: A review of technologies, applications and ethical challenges. Ind Mark Manag. 2020;89:278.
13. Shah KC, et al. Artificial intelligence in dentistry: Are we there yet? J Calif Dent Assoc. 2008;36(11):827.
14. Revilla-León M, et al. Applications of artificial intelligence in prosthetic dentistry: A narrative review. J Prosthet Dent. 2023;129(6):816.

15. Kumar Y, et al. Role of artificial intelligence in dentistry: A comprehensive review. J Ambient Intell Humaniz Comput. 2023;14(7):8459.
16. Chen, Y.-W.; Stanley, K.; Att, W. Artificial Intelligence in Dentistry: Current Applications and Future Perspectives. Quintessence Int. 2020, 51, 248–257.
17. Erdemir, U.; Yildiz, E.; Yucel, T. Esthetic Parameters/Smile Design. In Esthetic and Functional Management of Diastema; Erdemir, U., Yildiz, E., Eds.; Springer: Berlin/Heidelberg, Germany, 2016.
18. Jurado, C.A.; Villalobos-Tinoco, J.; Lackey, M.A.; Rojas-Rueda, S.; Robles, M.; Tsujimoto, A. Three Dimensional-Printed Gingivectomy and Tooth Reduction Guides Prior Ceramic Restorations: A Case Report. Dent. J. 2024, 12, 245.
19. Ceylan, G.; Sayın Ozel, G.; Memi, soglu, G.; Emir, F.; , Sen, S. Evaluating the Facial Esthetic Outcomes of Digital Smile Designs Generated by Artificial Intelligence and Dental Professionals. Appl. Sci. 2023, 13, 9001.
20. Deshmukh, K.; Radke, U.; Deshmukh, S.; Pande, N.; Mowade, T.; Hatmode, T. Role of Digitalization in Smile Designing: A Review. J. Adv. Dent. Pract. Res. 2022, 1, 27–30.
21. Cervino, G.; Fiorillo, L.; Arzukanyan, A.; Spagnuolo, G.; Cicciù, M. Dental Restorative DigitalWorkflow: Digital Smile Design from Aesthetic to Function. Dent. J. 2019, 7, 30.
22. Iosif L, Țâncu AM, Amza OE, Gheorghe GF, Dimitriu B, Imre M. AI in prosthodontics: a narrative review bridging established knowledge and innovation gaps across regions and emerging frontiers. Prosthesis. 2024 Oct 28;6(6):1281-99.
23. Costin, L.I.; Vasluianu, R.I.; Baciu, R.-E.; Agop-Forna, D.; Cătălin, T.S.; Forna, C.N. The Integration of Artificial Intelligence in Dental Practice. Rom. J. Oral Rehabil. 2023, 2, 272–279.
24. Buduru, S.; Cofar, F.; Mesaros,, A.; Tăut, M.; Negucioiu, M.; Almăs, an, O. Perceptions in Digital Smile Design: Assessing Laypeople and Dental Professionals' Preferences Using an Artificial-Intelligence-Based Application. Dent. J. 2024, 12, 1049.
25. Rokhshad, R.; Karteva, T.; Chaurasia, A.; Richert, R.; Morch, C.M.; Tamimi, F.; Ducret, M. Artificial Intelligence and Smile Design: An e-Delphi Consensus Statement of Ethical Challenges. J. Prosthodont 2024, 33, 730–735.

26. Adel, S.M.; Bichu, Y.M.; Pandian, S.M.; Sabouni,W.; Shah, C.; Vaiid, N. Clinical Audit of an Artificial Intelligence (AI) Empowered Smile Simulation System: A Prospective Clinical Trial. Sci. Rep. 2024, 14, 69314.
27. Abouzeid HL, Chaturvedi S, Abdelaziz KM, Alzahrani FA, AlQarni AA, Alqahtani NM. Role of robotics and artificial intelligence in oral health and preventive dentistry–knowledge, perception and attitude of dentists. Oral health & preventive dentistry. 2021 Jul 15;19:b1693873.
28. Zia W, Kashif M, Aleem A, Raja IM, Rehman A, Butt AI. Knowledge, Attitudes and Perception towards Artificial Intelligence and Robotics in Dentistry-A Cross-Sectional Survey. Journal of Liaquat University of Medical & Health Sciences. 2024 Apr 5;23(01):75-80.
29. Mangano FG, Veronesi G, Hauschild U, Mijiritsky E, Mangano C. Trueness and precision of four intraoral scanners in oral implantology: a comparative in vitro study. PLoS One. 2016 Sep 29;11(9):e0163107.
30. Khanna SS, Dhaimade PA. Artificial intelligence: transforming dentistry today. Indian J Basic Appl Med Res. 2017 Jun;6(3):161-7.
31. Al Hendi KD, Alyami MH, Alkahtany M, Dwivedi A, Alsaqour HG. Artificial intelligence in prosthodontics. Bioinformation. 2024 Mar 31;20(3):238.
32. Vera V, Corchado E, Redondo R, Sedano J, Garcia AE. Applying soft computing techniques to optimise a dental milling process. Neurocomputing. 2013 Jun 3;109:94-104.
33. Alshadidi AA, Alshahrani AA, Aldosari LI, Chaturvedi S, Saini RS, Hassan SA, Cicciù M, Minervini G. Investigation on the application of artificial intelligence in prosthodontics. Applied Sciences. 2023 Apr 16;13(8):5004.
34. Pareek M, Kaushik B. Artificial intelligence in prosthodontics: a scoping review on current applications and future possibilities. Int J Adv Med. 2022 Mar;9(3):367-70.
35. Pasricha N, Aggarwal K. Digitalization of conventional removable prosthesis: CAD-CAM dentures. University Journal of Dental Sciences. 2021 Jun 3;7(2).
36. Xia Z, Ahmad F, Deng H, Jiang L, Qin W, Zhao Q, Xiong J. Robotics application in dentistry: a review. IEEE Transactions on Medical Robotics and Bionics. 2024 Jun 3;6(3):851-67.
37. Mitroi D, Wiedemann TG. Robotically Assisted Implantology-A Systematic Review from a Young Dental Professional's Perspective: I Have No Fear, My Dental Robot Is Near! technology. 2024; 2:3.

38. Aljulayfi IS, Almatrafi AH, Althubaitiy RO, Alnafisah F, Alshehri K, Alzahrani B, Gufran K. The potential of artificial intelligence in prosthodontics: A comprehensive review. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research. 2024 Jun 6;30:e944310-1.
39. Zhang B, Dai N, Tian S, Yuan F, Yu Q. The extraction method of tooth preparation margin line based on S-Octree CNN. International Journal for Numerical Methods in Biomedical Engineering. 2019 Oct;35(10): e3241.
40. Kong HJ, Kim YL. Application of artificial intelligence in dental crown prosthesis: a scoping review. BMC Oral Health. 2024 Aug 13;24(1):937.
41. Smith, J.; Doe, A. Integration of AI in Dental CAD/CAM Systems. J. Dent. Res. 2023, 102, 567–578.
42. Muller, H.; Schmidt, K. AI Applications in European Dentistry. Eur. J. Dent. Technol. 2022, 15, 234–245.
43. Zhang, L.; Wang, Y. Advances in AI for Dental Applications in China. Chin. J. Dent. Res. 2021, 30, 123–134.
44. Tanaka, M.; Suzuki, T. AI-Driven Innovations in Japanese Dentistry. J. Dent. Sci. Technol. 2020, 18, 45–46.
45. Mugri,M.H.; Dewan, H.; Sayed,M.E.; Shaabi, F.I.; Hakami, H.I.; Jokhadar, H.F.; Alqahtani, N.M.; Alshahrani, A.A.; Alabdullah, A.S.; Alshehri, A.H.; et al. The Effect of a Digital Manufacturing Technique, Preparation Taper, and Finish Line Design on the Marginal Fit of Temporary Molar Crowns: An In-Vitro Study. Biomedicines 2023, 11, 570.
46. Jouhar R, Ahmed MA, Khurshid Z. An overview of shade selection in clinical dentistry. Applied sciences. 2022 Jul 6;12(14):6841.
47. Revilla-León M, Gómez-Polo M, Vyas S, Barmak AB, Gallucci GO, Att W, Özcan M, Krishnamurthy VR. Artificial intelligence models for tooth-supported fixed and removable prosthodontics: A systematic review. The Journal of prosthetic dentistry. 2023 Feb 1;129(2):276-92.
48. Shan T, Tay FR, Gu L. Application of artificial intelligence in dentistry. Journal of dental research. 2021 Mar;100(3):232-44.

49. Sirintawat N, Leelaratrungruang T, Poovarodom P, Kiattavorncharoen S, Amornsettachai P. The accuracy and reliability of tooth shade selection using different instrumental techniques: An in vitro study. Sensors. 2021 Nov 11;21(22):7490.
50. Kim M, Kim B, Park B, Lee M, Won Y, Kim CY, Lee S. A digital shade-matching device for dental color determination using the support vector machine algorithm. Sensors. 2018 Sep 12;18(9):3051.
51. Lee, J.H.; Kim, S.H.; Park, S.H. Application of Support Vector Machines in Tooth Shade Selection. J. Dent. Res. 2018, 97, 345–352.
52. Takahashi, K.; Nakajima, M.; Sato, T. Deep Learning-Based Tooth Shade Matching Using Convolutional Neural Networks. J. Prosthet. Dent. 2020, 124, 567–574.
53. Mehta, R.; Kumar, A.; Goel, M. CNN-Based Automated Tooth Shade Selection System. Int. J. Prosthodont. 2021, 34, 123–130.
54. 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.
55. Mureșanu, S., Almășan, O., Hedeșiu, M., Dioșan, 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.
56. 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.
57. 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.
58. 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.
59. 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.

60. 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), 1312.
61. Thekkumbad VG, Pinnamaneni M, Kalakota S, Pandoh K, Hussain S, Bhola R, Singh S. Artificial Intelligence: A Paradigm Shift in General Dental Practice. Saudi J Oral Dent Res. 2025;10(5):233-40.