Keywords
Artificial intelligence, Deep learning, Dental disease detection, Prosthodontic treatment planning, Digital dentistry

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Artificial Intelligence and Deep Learning Frameworks for Automated Dental Disease Detection and Prosthodontic Treatment Planning

Abstract

Artificial intelligence (AI) and deep learning are transforming dentistry by enabling automated disease detection, improving diagnostic accuracy, and enhancing prosthodontic treatment planning through data-driven clinical decision support. This review comprehensively examines contemporary AI and deep learning frameworks for automated dental disease detection, emphasizing their applications, diagnostic performance, integration into digital prosthodontic workflows, current limitations, and future research directions. Advanced AI techniques, including convolutional neural networks, object detection algorithms, image segmentation networks, vision transformers, and generative AI models, have demonstrated high potential for identifying dental caries, periodontal disease, periapical lesions, tooth wear, fractures, and occlusal abnormalities from clinical and radiographic images. Integration with digital technologies such as CAD/CAM systems, intraoral scanners, facial scanning, virtual articulators, and cloud-based platforms has further improved personalized treatment planning, workflow efficiency, and clinical decision-making. However, challenges including limited dataset diversity, insufficient external validation, model explainability, ethical concerns, data privacy, and regulatory compliance continue to hinder widespread clinical implementation. AI is expected to become an indispensable decision-support tool in prosthodontics. Future research should prioritize transparent, interoperable, and clinically validated AI systems to advance safe, evidence-based, patient-centered digital dentistry worldwide.

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INTRODUCTION

Artificial intelligence (AI) is undoubtedly one of the most impactful and innovative technologies in modern medicine, which provides an opportunity for evidence-based decision-making, improved diagnostics, and patient-tailored treatment regimens. The field of dentistry has recently seen a dramatic shift towards intelligent practice because of AI implementation, primarily machine learning (ML) and deep learning (DL) [1-3]. Using big clinical data and computing capabilities, AI allows detecting patterns that cannot be identified via visual observation only, thus improving the consistency and efficiency of diagnosis and treatment planning.

The identification of dental diseases largely depends upon proper analysis of radiographs, intraoral images, cone-beam computed tomography (CBCT), digital impressions, and the unique clinical history of the patient. Even with rapid advancements made in technology for imaging, diagnosis is subject to observer error, the experience of the clinician, workload, and complexity of the multidisciplinary approach to dental treatment [1,3,4]. Thus, incorrect or delayed diagnoses can have a negative effect on treatment results, especially when it comes to prosthodontic therapy, where thorough assessment and planning of oral structures is critical.

Recently, deep learning technologies have significantly enhanced the abilities of artificial detection systems to recognize various oral diseases. CNNs, object detection techniques, image segmentation techniques, and transformer models have exhibited extraordinary results when recognizing dental caries, periodontal bone loss, periapical diseases, tooth fractures, and malocclusions among others. There is great potential of these techniques in reducing variability in diagnosis and in the fast interpretation of images [5,6] In addition, automatic object detection techniques have been used in recognizing panoramic radiographs in the planning of treatment option.

AI not only helps in diagnosing diseases but also is progressively revolutionizing prosthodontic treatment planning through the use of digital methods that combine diagnostic information and provide personalized treatment planning solutions [7,8]. Current uses of AI range from digital smile design, prosthesis design optimization, implant planning, occlusion assessment, computer-aided design and manufacturing (CAD/CAM) fabrication and 3D printing technologies [9,10]. These smart systems have the ability to combine anatomic, functional, and aesthetic considerations to enable the selection of restorative solutions and enhance the workflow efficiency while minimizing the complexity of treatment planning.

However, there are still some limitations preventing the broad implementation of AI frameworks in prosthodontics [11]. The issue of non-generalization of models that were built on rather homogenous datasets with poor external validation is still a problem in prosthodontics. Other problems related to the development of AI algorithms in dentistry are the lack of interpretability of the black box models, ethical and legal issues, data privacy protection, and lack of standard validation procedures for clinical implementation of the models[5–10,12–15]. Moreover, even though the diagnostics has significantly improved, there are only a few research studies that assess the clinical efficacy of AI-based decision support systems in prosthodontics.

The extensive literature on the subject has indicated significant improvements in the use of AI to perform dental diagnoses and prosthodontics [16]. Nevertheless, it can be noted that there is a certain lack of a comprehensive review of these advancements in terms of specific diseases, AI computational architecture used, as well as clinical processes. An analysis of recent achievements in AI-assisted detection of dental conditions alongside the development of AI-assisted prosthodontics would be helpful in order to get a clearer picture of the area under consideration [17,18]. The aim of this paper is:

1.Critically assess the current state of artificial intelligence and deep learning algorithms in the context of computer-aided diagnosis of dental diseases in various imaging techniques

2.Investigate the uses of artificial intelligence in the planning of prosthetic treatments, particularly concerning digital workflows, decision support, and rehabilitation approaches

3.Determine the existing limitations, gaps in research, and future trends shaping the application of artificial intelligence in prosthodontics and restorative dentistry

2. Foundations of Artificial Intelligence and Deep Learning in Dentistry

2.1 Artificial Intelligence in Clinical Dentistry

The application of artificial intelligence (AI) has made it an important part of contemporary clinical dentistry by improving accuracy in diagnostics, treatment planning, risk predictions, and workflow optimization [19,20]. AI-enabled systems assist clinicians in making evidence-based decisions for dental treatment by analyzing various data sets related to patients, thus helping in providing more precise and efficient dentistry, particularly prosthodontics and restorative dentistry.

2.2 Machine Learning and Deep Learning

With machine learning (ML), computer programs can detect patterns and make predictions using clinical information without any programming, while in deep learning (DL), which is a specific branch of machine learning, multilayer neural networks can be used for automatic extraction of complex hierarchies from big data [21]. Machine learning and deep learning techniques have greatly contributed to dental image analysis and disease classification.

2.3 Computer Vision in Dental Imaging

Computer vision involves the application of AI techniques for image analysis in dentistry. Computer vision allows for the automated detection, segmentation, and classification of oral structures and diseases based on analysis of X-rays [22], cone beam computed tomography, intraoral images, and even those taken using smartphones

2.4 Neural Networks and Deep Learning Architectures

Biological neural networks mimic biological neural processing in order to detect the intricate relationships present in clinical data sets. On the other hand, advanced forms of deep learning, such as convolutional neural networks (CNNs) [24], are adept at feature extraction from images. Recent developments in CNN architecture, among others, have greatly improved diagnosis in dentistry.

2.5 Explainable Artificial Intelligence

XAI (Explainable AI) seeks to achieve transparency and explainability of AI decisions by elucidating the reasons behind algorithmic decision-making. In dentistry, the use of XAI allows clinicians to be more confident [25], to adhere to regulations, to ensure ethics, and to make a responsible use of AI-based diagnostic and treatment planning applications.

2.6 Generative Artificial Intelligence in Dentistry

GenAI is the next stage in the development of artificial intelligence, which allows for the production of clinically relevant information by generating text and images. In dentistry, various GenAI applications have been developed for such purposes as treatment planning, documentation, communication with patients [26], education, and digital workflow enhancement, although certain issues related to reliability, validation, and governance require attention (Table 1).

Table 1: Foundations of Artificial Intelligence and Deep Learning in Dentistry

Technology	Primary Function	Major Dental Applications	Key Benefit	References
Artificial Intelligence (AI)	Clinical decision support	Diagnosis, treatment planning, risk prediction	Improved clinical efficiency	[19-20]
Machine Learning (ML)	Pattern recognition and prediction	Disease prediction, outcome analysis	Learns from clinical data	[21]
Deep Learning (DL)	Automated feature extraction	Dental image analysis, disease detection	High diagnostic accuracy	[22]
Computer Vision	Image interpretation	Radiographs, CBCT, intraoral image analysis	Rapid and consistent diagnosis	[23]
Neural Networks (CNNs)	Image classification and segmentation	Caries, fractures, periodontal and periapical lesion detection	Superior image analysis	[20,21]
Explainable AI (XAI)	Transparent decision-making	Clinical decision support	Improved clinician trust	[22]
Generative AI (GenAI)	Content generation and reasoning	Treatment planning, education, documentation	Enhanced workflow efficiency	[24]

3. Digital Data Sources for AI-Driven Dental Disease Detection

Detection of dental diseases using AI relies heavily on the source of high-quality and relevant digital data that is used to develop and validate machine learning models. Intraoral images are rich in visual information which is useful in diagnosing caries, plaque deposits, gingival inflammation, tooth discolourations, and soft tissue alterations. Panoramic images continue to play an important role in the overall assessment of dentition, alveolar bone, impacted teeth, periapical diseases, and periodontal bone destruction, while periapical images allow for more detailed visualization of local carious, endodontic, and periapical diseases [25]. CBCT allows the diagnosis of bone abnormalities, root canal morphology, periapical diseases, implants, and maxillofacial structures in a 3D manner [26,27,28]. Digital scans and impressions allow the acquisition of surface-based datasets that are helpful in detecting tooth wear, malocclusion, tooth preparation margin, arch relationship, and anatomical anomalies for prosthodontics. The use of electronic dental records helps collect information about longitudinal clinical, demographic, periodontal, restorative, medical, and behavioral factors that enable prediction of risk for a certain disease, disease progression, and provision of personalized prevention and treatment strategies (Figure 1) [29]. The combination of different types of multimodal data is getting more and more important in the field of AI in dentistry since their integration into a unified system provides higher diagnostic performance than that of the single modality approaches [30-33]. Nonetheless, there are several aspects of such data that need to be taken into consideration in order for them to be clinically relevant.

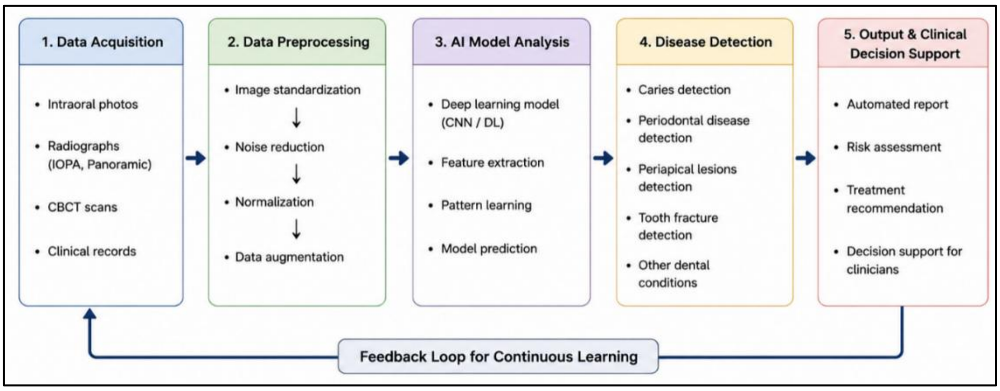

Figure 1: Artificial Intelligence Workflow for Automated Dental Disease Detection

Figure 1 depicts The Workflow of AI-Based Dental Disease Diagnosis, which consists of data collection, pre-processing, AI model analysis, disease identification, and decision support, with a continuous feedback loop incorporated.

4. Artificial Intelligence Frameworks for Automated Dental Disease Detection

4.1 Dental Caries Detection

AI models assist in early detection and monitoring of dental caries through image analysis of radiographs and optical images with a high level of diagnostic precision. Deep learning models detect minor signs of demineralization that may go unnoticed clinically [34], helping in designing personalized prevention measures and restorations.

4.2 Periodontal Disease Assessment

AI technology plays a role in the evaluation of periodontitis through the automatic analysis of clinical and radiographic features such as periodontal bone loss, attachment issues, and inflammation [35]. Artificial intelligence technology is helpful in diagnosing periodontal disease consistently and evaluating disease progression in decision-making.

4.3 Periapical Lesion Detection

Periapical lesions can be identified and segmented using deep learning algorithms based on panoramic radiograph images and CBCT images [36]. Image processing techniques aid doctors in detecting apical pathology, making the diagnosis more reliable and helping in treatment planning.

4.4 Tooth Wear Analysis

The image analysis through AI can objectively assess tooth wear through changes in morphology observed from digital images and clinical pictures [37]. The automated analysis helps in early diagnosis of attrition, abrasion, and erosion along with the prevention and restoration plans.

4.5 Vertical Root Fracture Detection

The machine learning models enable better identification of the minute radiographic findings associated with vertical root fractures through improved accuracy [38]. The use of artificial intelligence helps detect these fractures earlier in time while reducing the risk of misdiagnosis.

4.6 Pulpal Pathology Assessment

AI is able to combine clinical data with radiographic images and helps in distinguishing reversible and irreversible pulpal diseases [39,40]. AI-enabled decision support aids in the differentiation between reversible and irreversible pulp conditions, contributing to the accuracy of diagnosis and optimization of treatment.

4.7 Cracked Tooth Identification

AI-based models facilitate the detection of crack propagation through automated analysis of imaging and structural features of the teeth. The timely detection of crack propagation improves the prognosis for the affected teeth and helps clinicians choose appropriate treatment strategies [41].

4.8 Tooth Loss Prediction

Models based on machine learning are used to identify the probability of tooth loss through the combination of demographic, periodontal, restorative, and behavioral factors [42]. The use of predictive analytics allows for individual risk identification and preventive planning, thereby enhancing personalized dental care.

4.9 Occlusal Abnormality Detection

With the help of artificial intelligence, computerized assessment of occlusal deviations is possible using digital occlusal data, dental models, and images [43]. Such systems aid clinicians to recognize any functional irregularities, malocclusions, and TMJ disorders.

4.10 Alveolar Bone Evaluation

The examination of alveolar bone anatomy, thickness, and density is made possible through the analysis of CBCT data using artificial intelligence techniques. Automated bone analysis assists in dental implant planning, prosthetic rehabilitation, periodontal assessment, and surgery planning (Table 2) [44]

Table 2: Artificial Intelligence Applications in Dental Disease Detection

Disease	AI Application	Imaging Modality	Reference(s)
Dental caries	Automated detection	Bitewing, IOPA	[34]
Periodontal disease	Bone loss assessment	Panoramic, CBCT	[35]
Periapical lesions	Lesion detection	IOPA, CBCT	[36]
Tooth wear	Surface evaluation	Digital scans	[37]
Vertical root fracture	Machine learning diagnosis	CBCT	[38]
Pulpal pathology	Clinical decision support	Clinical + Radiographs	[39,40]
Cracked tooth	Crack recognition	Clinical imaging	[41]
Tooth loss	Risk prediction	Clinical records	[42]
Occlusal abnormalities	Functional analysis	Digital models	[43]
Alveolar bone	Bone thickness assessment	CBCT	[44]

5. Deep Learning Frameworks Used in Dental Diagnostics

The reason behind deep learning becoming the foundation of artificial intelligence-based dental diagnostics is due to its capabilities of automatic extraction of hierarchical features from complex imaging data without any manual engineering of those features. In terms of these architectures, CNNs have been the most widely used type of framework for dental caries, periodontitis, periapical pathology, dental fractures, and anatomical abnormalities detection from radiographs, CBCT, and intraoral imaging, offering the highest level of diagnostics accuracy and stability [45,46]. Object detection framework that

includes YOLO (You Only Look Once), Faster R-CNN, and RetinaNet offers fast tooth, implant, carious lesion and other pathological finding identification while preserving high level of detection accuracy, being therefore useful for clinical decision-making in real time [47]. Segmentation of the image by means of U-Net, Mask R-CNN and other neural networks is helpful in providing accurate measurement of lesions, bone loss, and anatomical borders of the teeth, which is necessary for diagnosis (Figure 2).
Vision Transformers (ViT), on the other hand, are more recent alternatives that have been introduced to address the issue of identifying long-range spatial dependencies present in dental imagery and thus enhancing feature extraction in complicated medical diagnostic procedures [48,49]. Moreover, hybrid and ensemble models, which utilize a combination of several deep learning models or incorporate traditional machine learning techniques, have shown increased prediction accuracy and generalization when compared to single-model strategies [50,51,52]. Finally, the problem of data exchange and patient privacy is solved by federated learning, which provides for the joint training of the model using data from various facilities, without passing any information about the patients [53].

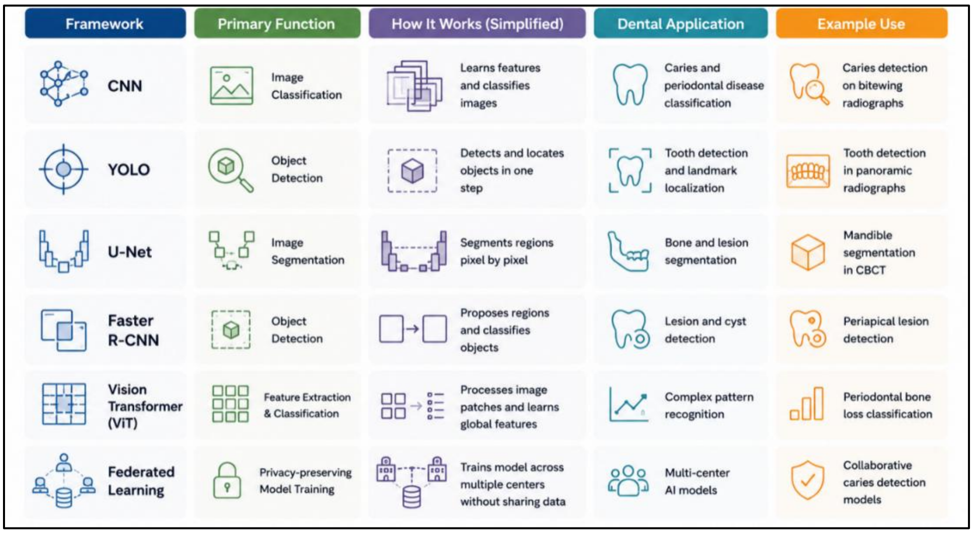

Figure 2: Deep Learning Frameworks Used in Dental Diagnostics

Figure 2 illustrates the Overview of AI Frameworks in Dentistry, showcasing their main functionalities, operational mechanisms, clinical applications, and specific examples of their implementation in diagnosis, detection, segmentation, and treatment planning.

6. Artificial Intelligence for Prosthodontic Treatment Planning

Through artificial intelligence (AI), prosthetic treatment planning is becoming more advanced as it allows for incorporating patient-specific clinical, radiographic, and digital data into comprehensive decision-making frameworks that enhance diagnostic accuracy, process efficiency, and predictable outcomes. AI-based patient evaluation involves gathering information about the patient's medical history, intraoral findings, 3D imaging, and digital impressions in order to perform personalized diagnosis and risk assessment before proceeding with rehabilitation [54]. Within digital smile design, AI technology analyzes facial symmetry, lip movement, tooth dimensions, and other aesthetic parameters to provide personalized treatment planning in accordance with the functional and aesthetic goals [55]. Occlusal analysis based on AI technology further allows for the precise evaluation of occlusal contacts, jaw movements, and force distribution, reducing functional problems and leading to better prosthetic results [56].
Further to the diagnosis, the optimization of AI-facilitated prosthesis design takes into account biomechanical, anatomical and esthetic factors and provides optimal restorative designs for crown, bridge, veneer and implant-prosthetic rehabilitation while optimizing the workflow of CAD/CAM processes [57]. In the field of fixed and removable prosthodontics, the machine learning algorithms help to determine which prosthesis to choose, select the type of material for fabrication, provide framework design guidance and make outcome prediction, thus making possible the development of personalized rehabilitation approaches [58]. The considerable role of artificial intelligence in implant prosthodontics has been proved by its capability to assess the quality of bone, anatomical limitations, implant position, prosthetic emergence profile and peri-implant conditions using the deep learning approach [59]. Moreover, the implementation of AI is very beneficial for providing full-mouth rehabilitation based on the integration of multidisciplinary diagnostic information into a treatment plan, taking into account esthetic, functional and long-term considerations (Table 3) [60]. Emerging clinical decision support systems combine patients' information with evidence-based recommendations and help dentists to select the appropriate treatment pathway [61].

Table 3: Artificial Intelligence Applications in Prosthodontic Treatment Planning

Prosthodontic Stage	AI Application	Clinical Benefit	Reference(s)
Patient evaluation	Risk assessment	Personalized diagnosis	[54,55]
Smile design	Facial analysis	Esthetic planning	[54,56]
Occlusal analysis	Bite evaluation	Functional optimization	[57]
Tooth preparation	Margin assessment	Standardized preparation	[54,55]
Prosthesis design	CAD optimization	Accurate restoration	[58]
Fixed prosthodontics	Crown/bridge planning	Predictable outcomes	[55,56]
Removable prosthodontics	Denture design	Improved adaptation	[59]
Implant prosthodontics	Implant positioning	Surgical accuracy	[58,59]
Full-mouth rehabilitation	Treatment sequencing	Multidisciplinary planning	[60]
Clinical decision support	AI recommendations	Reduced variability	[61]

7. Integration of Artificial Intelligence into the Digital Prosthodontic Workflow

7.1 CAD/CAM Technologies

In fact, AI has played an important role in enhancing the quality of CAD/CAM systems through automation of restoration designs, margin detections, and accurate fabrication of prosthetics. In addition, intelligent algorithms help to carry out effective digital processes without any human interventions, errors during manufacturing, and treatment time [62].

7.2 Intraoral Scanning

AI-powered intraoral scanners make high-quality scans due to a reduction in stitching artifacts, optimized imaging processes, and automatic anatomical landmark detection [63]. Better scan accuracy improves diagnostics, fit, and communications among clinicians and dental labs for fully digital treatment planning.

7.3 Facial Scanning

AI-assisted facial scanning provides detailed analysis of facial morphology, symmetry, and soft tissue dynamics, allowing for esthetic prosthodontics treatment planning [64]. Automated identification of facial landmarks makes it possible to design individualized smiles and harmoniously integrate prosthetic restorations with specific facial features of the patients.

7.4 Virtual Articulators

Virtual articulators, which utilize AI technology, can accurately simulate mandibular movement and occlusal relationship, unlike conventional mechanical articulators. These modern tools increase the accuracy of occlusal analysis and prosthesis adaptation, decrease chair adjustments, and increase the predictability of the treatment [65].

7.5 Digital Occlusion Analysis

AI improves occlusion analysis in dentistry through objective evaluation of occlusal contacts, forces applied and mandibular movement [66]. Automation makes it easier to avoid mistakes in interpreting the findings and make occlusal adjustments that promote prosthetic durability.

7.6 Three-Dimensional Printing

Integration of artificial intelligence enhances the 3D printing process in prosthetic dentistry through optimization of design, manufacture, and quality control [67]. The synergy makes it possible to create customized restorations with increased accuracy and efficiency.

7.7 Cloud-Based Digital Dentistry

Digital dentistry in the cloud involves combining AI with cloud computing capabilities, such as storing information centrally and processing it efficiently. Cloud computing allows real-time information sharing between healthcare providers, laboratories, and specialists (Figure 3) [68].

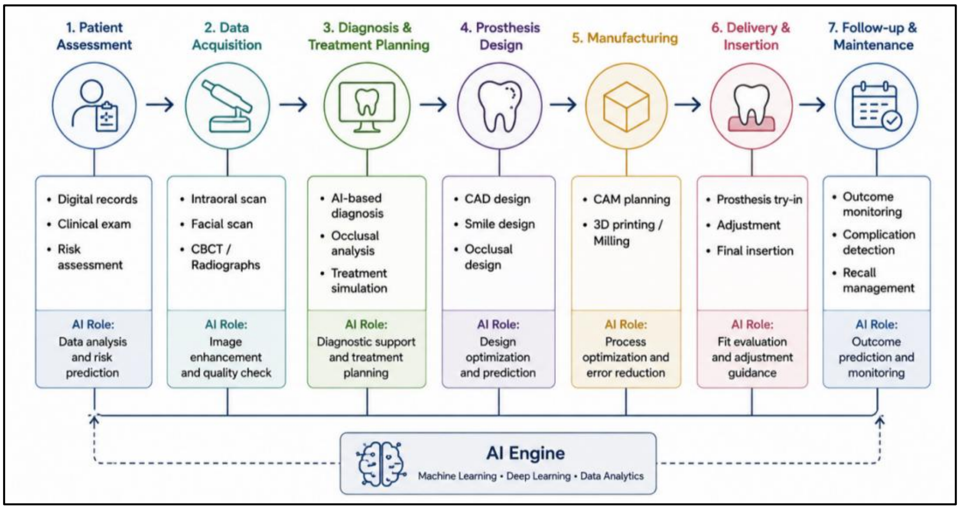

Figure 3: Integration of AI into the Digital Prosthodontic Workflow

Figure 3 illustrates the AI-driven digital workflow in prosthodontics, showing how the process from patient evaluation, data collection, diagnostics, prosthesis design, fabrication, delivery, to post-delivery care involves the use of AI in decision-making, automation, optimization, and result prediction.

8. Clinical Performance of Artificial Intelligence Systems

AI systems' clinical performance should be measured using clinically meaningful and context-specific metrics prior to their use in dental diagnosis and prosthodontics. Accuracy represents the general measure of correct classifications. Nevertheless, it can be highly misleading in case of unbalanced disease prevalence, and therefore the sensitivity and specificity become important parameters to define whether the model is able to correctly recognize diseased and healthy patients [69]. Precision and recall help to define the reliability of the positive prediction and the capability of the model to detect all the clinically relevant abnormalities, especially in the case of screening when missing disease can harm the patient's health [70,71]. External validation becomes a crucial necessity since many AI systems show high performance in the internal dataset but lower reliability in external clinical samples, different imaging equipment, institutions, and acquisition protocols [72].

It is just as critical for the dentistry field because anatomical differences, age, ethnicity, severity of the disease, condition of restoration, and imaging quality may affect AI performance and applicability [73]. Comparing the AI systems to the performance of clinicians also adds translational value by finding out whether AI can perform at the level of, or even better than, humans in diagnosis. The evidence on the clinical use of AI indicates that decision support systems are able to increase efficiency of recognition, decrease variability of diagnostics and provide improvements in care delivery if used properly and monitored [74,75]. However, performance assessment must go beyond the use of metrics to include such aspects as calibration, interpretability, workflow implications, safety monitoring, cost-effectiveness, and post-deployment performance monitoring. Continuous monitoring is needed because of the possibility of declining performance caused by changing datasets, shifting clinical practice, and innovations in imaging technology [76]. Therefore, it is crucial to validate and monitor performance of the algorithms used (Table 4).

Table 4: Clinical Performance Metrics of Artificial Intelligence Systems

Performance Metric	Clinical Importance	Application	Reference(s)
Accuracy	Overall performance	Diagnosis	[69]
Sensitivity	Disease detection	Screening	[70]
Specificity	Healthy case recognition	Differential diagnosis	[71]
Precision	Reliability of predictions	Decision support	[72]
Recall	Completeness of detection	Early diagnosis	[72,73]
External validation	Robustness	Clinical translation	[74]
Generalizability	Population applicability	Multi-center implementation	[75]
Clinician comparison	Human-AI benchmarking	Workflow integration	[76]

9. Clinical Applications and Translational Impact

9.1 Chairside Diagnostic Support

Chair-side diagnostics that are AI-driven make real-time evaluations of patient images, radiographs, and medical records, allowing for the diagnosis of oral diseases in a timely manner [77]. They ensure accurate diagnosis, lower the workload of the clinician, and help in intervention in prosthodontics and restorative dentistry.

9.2 Treatment Planning Optimization

Using AI, treatment planning is enhanced by combining clinical, imaging, and digital workflow information to develop customized therapy recommendations [78]. Decision-support systems automate treatment processes to reduce planning variation and help clinicians in choosing an efficient method of restoring complex cases.

9.3 Personalized Prosthodontics

Personalized Prosthetics with the help of AI is done by integrating the specific anatomy, function, esthetic and biomechanics of the patient into an individual treatment plan [79]. AI helps in designing custom prosthesis, selecting the right material and predicting the outcome of treatment.

9.4 Workflow Automation

AI-driven workflow automation helps simplify routine work within clinical and laboratory settings such as documentation, digital designing, patient management, and prosthesis manufacturing [80]. Automating workflows increases efficiency, eliminates human error, promotes collaboration among different specialists, and lets clinicians concentrate on more complicated activities requiring decisions based on patients' needs.

9.5 Tele-Dentistry and Remote Consultation

Teledentistry incorporating AI allows for tele-diagnosis and teleconsultation, as well as follow-up through the secure transmission of digital records, radiographs, and intraoral images [81]. This technology increases the accessibility of prosthetic dentistry care, promotes interdisciplinary communication, and allows for continual patient monitoring outside the clinical setting.

9.6 Precision Dentistry

In precision dentistry, artificial intelligence and digital tools along with biological data unique to each individual are used to provide personalized treatment solutions for prevention and restoration of health [82]. Through prediction and digital prosthodontics, artificial intelligence ensures highly precise diagnostic and rehabilitative solutions as well as optimized treatment outcomes (Figure 4).

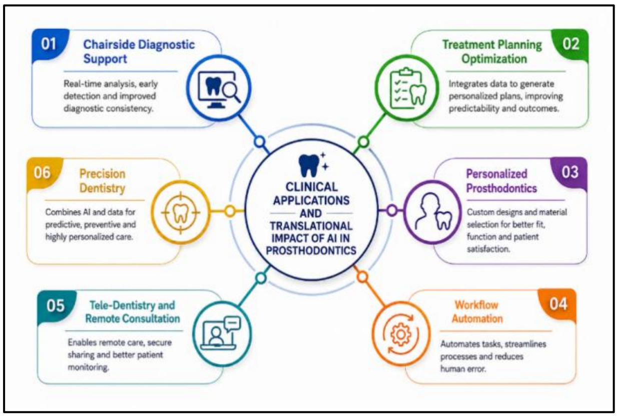

Figure 4: Clinical Applications of AI in Prosthodontics

Figure 4 shows the Clinical applications and Translational impact of Artificial Intelligence in Prosthodontics with emphasis on its use for diagnosis, treatment planning, custom prosthesis manufacturing, automation, tele-dentistry, and precision dentistry.

10. Current Challenges and Limitations

Although there has been a remarkable progress in artificial intelligence (AI) applications in dentistry, there are still many obstacles that prevent its extensive use in the clinical environment. The performance of AI algorithms strongly depends on the existence of high-quality, large-scale, well-curated databases; nonetheless, many available datasets lack both variety and representativeness, posing a risk of data annotation bias and lack of generalizability. Besides, a "black box" aspect of some algorithms hampers their interpretability. Robust clinical evaluation of AI systems with the help of multicenter prospective studies is still deficient. Algorithmic bias, accountability issues, and ethical considerations regarding informed consent pose serious challenges and demand elaborated governance approaches. Protection of patient privacy, including secure storage and cybersecurity of electronic health records, is also an important task due to an increasing use of AI systems. Furthermore, regulatory approval is difficult due to the fact that there is yet no set standards for the assessment of AI-driven dental devices. Lastly, there are barriers towards adoption of AI in clinical settings due to the expense of implementation, lack of digital infrastructure, insufficient training of clinicians, non-interoperable systems, and reluctance to change the workflow process. In solving all these shortcomings through the use of standardized datasets, transparent algorithms, and validations, among others, would prove very important for the future of AI dentistry.

11. Emerging Trends, Research Gaps, and Future Perspectives

Future trends in AI are bound to play a huge role in the future of dental disease diagnosis and prosthodontic treatment planning. Explainable AI is one way of improving the process since the clinician will be able to know how certain diagnostic or treatment suggestions are arrived at hence increasing clinical accountability and trust in the AI system. Foundation models and next-generation deep learning are some of the AI concepts that can be useful in making generalizations in areas such as imaging modalities, diseases, and patient population. Large language models can help in clinical decision-making, prosthodontic training, patient interaction, and documentation, but need careful validation of results. The use of digital twins and virtual patients might enable simulation of treatment results before any action is taken, while autonomous decision support systems can help physicians during complicated rehabilitation processes. Future precise prosthodontics might involve individualized AI-based models with consideration of anatomical, functional, aesthetic, and biological parameters. At the same time, there are many shortcomings such as the absence of large multicenter datasets, validation of results, annotated data for prosthodontics, interoperability, and lack of explainability of the models. In the future, it is necessary to conduct prospective clinical trials, analyze costs, regulate the application of AI in medicine, and develop a human-centered workflow.

12. Conclusion

Through the application of artificial intelligence (AI) and deep learning techniques, there has been significant progress in the field of disease detection and prosthodontic treatment planning in dentistry due to fast and data-driven decision-making process. Computer vision and deep learning have made it possible to detect oral diseases automatically and plan personalized prosthodontic rehabilitation through the use of diagnostic and planning processes which utilize AI technology. In addition, the combination of AI technology with other digital technologies like CAD/CAM systems, intraoral scanner, facial scanner, virtual articulator, and cloud computing platforms has made this process easier. However, some challenges persist which hinder the implementation of these technologies in the clinic. These challenges include the issue of heterogeneous datasets, insufficient external validation, interpretability of models, ethics of usage of the model, regulations and lack of interoperability. These issues need to be solved through standardizing of data sets, developing transparent algorithms, multicenter clinical validation and governance frameworks. The future of explainable artificial intelligence, multimodal learning, foundation models, and digital twins is anticipated to enhance diagnostic accuracy and patient-specific treatment planning. Instead of replacing doctors, AI technologies must be understood as a smart decision-making tool that works alongside professional knowledge to optimize the process of treatment. Collaboration between prosthodontists, researchers, engineers, regulators, and industry participants will be vital in transforming innovative AI tools into practice.

REFERENCES

1. Moeini A, Torabi S. The role of artificial intelligence in dental diagnosis and treatment planning. Journal of Oral and Dental Health Nexus. 2025 Jan 1;2(1):14-26.
2. Dawa H, Aroso C, Vinhas AS, Mendes JM, Cortes AR. Artificial Intelligence Architectures in Oral Rehabilitation: A Focused Review of Deep Learning Models for Implant Planning, Prosthodontic Design, and Peri-Implant Diagnosis. Applied Sciences. 2026 Apr 10;16(8):3739.
3. Nambiar R, Nanjundegowda R. A comprehensive review of ai and deep learning applications in dentistry: From image segmentation to treatment planning. Journal of Robotics and Control (JRC). 2024 Sep 18;5(6):1744-52.
4. Rashidi Ranjbar F, Zamanifar A. Autonomous dental treatment planning on panoramic x-ray using deep learning based object detection algorithm. Multimedia Tools and Applications. 2024 Apr;83(14):42999-3033.
5. Khaohoen A, Yoda N, Rungsiyakull P, Rungsiyakull C, Taichi T. Can artificial intelligence optimize treatment planning and outcome prediction in fixed tooth-and implant-supported prosthodontics? A scoping review. BMC Oral Health. 2025 Dec 11.
6. Samaranayake L, Tuygunov N, Schwendicke F, Osathanon T, Khurshid Z, Boymuradov SA, Cahyanto A. Artificial intelligence in prosthodontics: transforming diagnosis and treatment planning. Asian Journal of Periodontics and Orthodontics. 2024;4(1-2024):9-18.
7. Ajantha J, Beulah AA, Eswaran MA, Ranjani T. Artificial Intelligence-Driven Approaches in Prosthodontic Treatment Planning: A Review. international journal of research and reports in dentistry. 2025 Nov 20;8(2):523-35.
8. Najeeb M, Islam S. Artificial intelligence (AI) in restorative dentistry: current trends and future prospects. BMC Oral Health. 2025 Apr 18;25(1):592.
9. Ahmed R. The Role of Artificial Intelligence in Modern Dentistry: Transforming Diagnosis and Treatment Planning. Dentistry. 2025;1:100001.
10. 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.
11. Gao S, Wang X, Xia Z, Zhang H, Yu J, Yang F. Artificial intelligence in dentistry: A narrative review of diagnostic and therapeutic applications. Medical science monitor: international medical journal of experimental and clinical research. 2025 Apr 8;31:e946676.
12. Rokhshad R, Khosravi K, Motie P, Sadeghi TS, Tehrani AM, Zarbakhsh A, Revilla-León M. Deep learning applications in prosthodontics: A systematic review. The Journal of Prosthetic Dentistry. 2025 May 13.
13. Shekarappa C, Dasu L, Preethi P, Devi SK, Arampurath A. Artificial Intelligence-powered Dentistry: Enhancing Patient Care and Efficiency. CODS-Journal of Dentistry. 2025 Feb 20;16(1):15-9.
14. Gao, S., Wang, X., Xia, Z., Zhang, H., Yu, J., & Yang, F. (2025). Artificial intelligence in dentistry: A narrative review of diagnostic and therapeutic applications. Medical science monitor: international medical journal of experimental and clinical research, 31, e946676.
15. Ding H, Wu J, Zhao W, Matinlinna JP, Burrow MF, Tsoi JK. Artificial intelligence in dentistry—A review. Frontiers in Dental Medicine. 2023 Feb 20;4:1085251.
16. Shaikh K, Bekal SV, Marei HF, Elsayed WS, Surdilovic D, Jawad LA. Artificial intelligence in dentistry. Berlin, Germany: Springer; 2023.
17. Möller DP. Machine learning and deep learning. InGuide to cybersecurity in digital transformation: trends, methods, technologies, applications and best practices 2023 Apr 19 (pp. 347-384). Cham: Springer Nature Switzerland.
18. Taye MM. Understanding of machine learning with deep learning: architectures, workflow, applications and future directions. Computers. 2023 Apr 25;12(5):91.
19. Alharbi SS, Alhasson HF. Exploring the applications of artificial intelligence in dental image detection: A systematic review. Diagnostics. 2024 Oct 31;14(21):2442.
20. Farook TH, Ahmed S, Jamayet NB, Dudley J. Computer vision with smartphone microphotography for detection of carious lesions. Intelligence-Based Medicine. 2023 Jan 1;8:100105.
21. Vakalopoulou M, Christodoulidis S, Burgos N, Colliot O, Lepetit V. Deep learning: basics and convolutional neural networks (CNNs). Machine learning for brain disorders. 2023 Jul 23:77-115.
22. Cong S, Zhou Y. A review of convolutional neural network architectures and their optimizations. Artificial Intelligence Review. 2023 Mar 1;56(3):1905.
23. Minh D, Wang HX, Li YF, Nguyen TN. Explainable artificial intelligence: a comprehensive review. Artificial Intelligence Review. 2022 Jun;55(5):3503-68.
24. Saranya A, Subhashini R. A systematic review of Explainable Artificial Intelligence models and applications: Recent developments and future trends. Decision analytics journal. 2023 Jun 1;7:100230.

25. Villena F, Véliz C, García-Huidobro R, Aguayo S. Generative artificial intelligence in dentistry: current approaches and future challenges. arXiv preprint arXiv:2407.17532. 2024 Jul 24.
26. Dawa H, Cortes AR, Ribeiro C, Neves J, Vicente H. Integrating Generative Artificial Intelligence in Clinical Dentistry: Enhancing Diagnosis, Treatment Planning, and Procedural Precision Through Advanced Knowledge Representation and Reasoning. Digital. 2025 Sep 18;5(3):44.
27. Badr W, Alshehri BH, Abuljadayel GM, Rashedi HE, Julidan M. Digital and AI-Driven Diagnostic Technologies in Oral Health: A Systematic Review with Implications for Precision and Translational Dentistry. Genetics and Molecular Research. 2025 Dec 31;24(4):1-8.
28. Bhosale YH, Gantayat SS, Rane K, Mohana TK, Ramya C, Shanmugasundaram K. AI-Driven Predictive Models for Early Detection of Periodontal Disease: A Data Management Approach in Clinical Dentistry.
29. Falkner S. Real-Time Oral Health Monitoring: AI-Driven Biosensors in Dental Practice. Glob J Med Biomed Case Rep. 2025;1:012.
30. Cheng B, Xiang M, Zhao Z, Zhang X, Wang YF, Ge S, Zhao F, Li M, Wang H. Artificial intelligence-driven segmentation of three oral diseases: Enabling precision diagnosis and decision support. international dental journal. 2026 Jun 1;76(3):109486.
31. Nayak PP, Shetty V, Zacharias L, Gore I. AI-driven approaches in the management of early childhood caries: A path toward global oral health. Journal of Oral Biology and Craniofacial Research. 2025 Sep 1;15(5):1134-40.
32. Liang Y, Li D, Deng D, Chu CH, Mei ML, Li Y, Yu N, He J, Cheng L. AI-driven dental caries management strategies: from clinical practice to professional education and public self care. International dental journal. 2025 Aug 1;75(4):100827.
33. Rajmalani M. Role of artificial intelligence in dental diagnostics. Journal of Advanced Medical and Dental Sciences Research. 2025 May 1;13(5):5-12.
34. Batra AM, Reche A. A new era of dental care: harnessing artificial intelligence for better diagnosis and treatment. Cureus. 2023 Nov 23;15(11).
35. Veseli E, Mehrabanian M, Ammar N. The potential of artificial intelligence in the early detection of systemic diseases during routine dental care: The potential of artificial intelligence in the early detection of systemic diseases during routine dental care. British Dental Journal. 2025 Aug 8;239(3):168-74.
36. Marappan R. AI-Driven Approaches for Enhancing Early Detection of Dental Caries. In2025 International Conference on Intelligent Computing and Knowledge Extraction (ICICKE) 2025 Jun 6 (pp. 1-5). IEEE.
37. Kabir T, Lee CT, Chen L, Jiang X, Shams S. A comprehensive artificial intelligence framework for dental diagnosis and charting. BMC Oral Health. 2022 Nov 9;22(1):480.
38. Zhu J, Chen Z, Zhao J, Yu Y, Li X, Shi K, Zhang F, Yu F, Shi K, Sun Z, Lin N. Artificial intelligence in the diagnosis of dental diseases on panoramic radiographs: a preliminary study. BMC Oral Health. 2023 Jun 3;23(1):358.
39. Abdelaziz M. Detection, diagnosis, and monitoring of early caries: the future of individualized dental care. Diagnostics. 2023 Dec 12;13(24):3649.
40. Chan EK, Wah YY, Lam WY, Chu CH, Yu OY. Use of digital diagnostic aids for initial caries detection: a review. Dentistry journal. 2023 Sep 28;11(10):232.
41. Salvi GE, Roccuzzo A, Imber JC, Stähli A, Klinge B, Lang NP. Clinical periodontal diagnosis. Periodontology 2000. 2023 Jul 14.
42. Jacobs R, Fontenele RC, Lahoud P, Shujaat S, Bornstein MM. Radiographic diagnosis of periodontal diseases–Current evidence versus innovations. Periodontology 2000. 2024 Jun;95(1):51-69.
43. Cotti E, Schirru E. Present status and future directions: Imaging techniques for the detection of periapical lesions. International endodontic journal. 2022 Oct;55:1085-99.
44. Wang R, Zhu Y, Chen C, Han Y, Zhou H. Tooth wear and tribological investigations in dentistry. Applied Bionics and Biomechanics. 2022;2022(1):2861197.
45. Ran S, Wang Q, Wang J, Huang J, Zhou W, Zhang P, Yuan K, Cheng Y, Gu S, Zhu J, Huang Z. Diagnosis of in vivo vertical root fracture in endodontically treated teeth using machine learning techniques. Journal of Endodontics. 2025 May 13.
46. Barani M, Aliu X, Ajeti N, Asllani L. Assessment of correlation between clinical, radiographic, microbiological, and histopathological examinations in identification of pulpal diseases-a single-centre study. The Saudi Dental Journal. 2023 Jul 1;35(5):540-6.
47. de Toubes KM, Soares CJ, Soares RV, de Souza Côrtes MI, Tonelli SQ, Bruzinga FF, Silveira FF. The correlation of crack lines and definitive restorations with the survival and success rates of cracked teeth: a long-term retrospective clinical study. Journal of Endodontics. 2022 Feb 1;48(2):190-9.
48. Hasuike A, Watanabe T, Wakuda S, Kogure K, Yanagiya R, Byrd KM, Sato S. Machine learning in predicting tooth loss: a systematic review and risk of bias assessment. Journal
49. Yuryevich IS. ORTHODONTIC TREATMENT OF PATIENTS WITH OCCLUSION ANOMALIES IN THE SAGITTAL PLANE COMPLICATED BY INTERNAL DISORDERS OF THE TMJ.
50. Wright AR. Assessing Alveolar Bone Thickness in the Mandibular Incisor Region in Different Malocclusions Using CBCT Imaging (Master's thesis, Nova Southeastern University).
51. Bouali R, Mahboub O, Lazaar M. Review of dental diagnosis by deep learning models: trends, applications and challenges. Procedia Computer Science. 2024 Jan 1;231:221-8.
52. Sivari E, Senirkentli GB, Bostanci E, Guzel MS, Acici K, Asuroglu T. Deep learning in diagnosis of dental anomalies and diseases: A systematic review. Diagnostics. 2023 Jul 27;13(15):2512.
53. Khurshid Z, Osathanon T, Alharbi AS, Egusa H. Applications for the YOLO deep learning framework in dentistry: a narrative review. Journal of Prosthodontic Research. 2026:JPR_D_25_00374.

54. Alanazi MQ. Deep learning models and dental diagnosis: A review. J Clin Med Images Case Rep. 2024;4(4):1720.
55. Forouzeshfar P, Safaei AA, Ghaderi F, Hashemi Kamangar S, Kaviani H, Haghi S. Dental caries diagnosis using neural networks and deep learning: a systematic review. Multimedia Tools and Applications. 2024 Mar;83(10):30423-66.
56. Parkhi P, Harjal S, Sahu A, Agrawal P, Shingne H, Bobde Y, Padole A. A Comprehensive Deep Learning Framework for Dental Disease Classification. Journal Européen des Systèmes Automatisés. 2025 Mar 1;58(3).
57. Khattak O, Hashem AS, Alqarni MS, Almufarrij RA, Siddiqui AY, Anis R, Ahmad S, Fareed MA, Alothmani OS, Alkhershawy LH, Alabidin WW. Deep learning applications in dental image-based diagnostics: A systematic review. InHealthcare 2025 Jun 18 (Vol. 13, No. 12, p. 1466). MDPI.
58. Chen ID, Yang CM, Chen MJ, Chen MC, Weng RM, Yeh CH. Deep learning-based recognition of periodontitis and dental caries in dental x-ray images. Bioengineering. 2023 Aug 1;10(8):911.
59. Sohrabniya F, Hassanzadeh-Samani S, Ourang SA, Jafari B, Farzinnia G, Gorjinejad F, Ghalyanchi-Langeroudi A, Mohammad-Rahimi H, Tichy A, Motamedian SR, Schwendicke F. Exploring a decade of deep learning in dentistry: A comprehensive mapping review. Clinical Oral Investigations. 2025 Feb 19;29(2):143.
60. Li X, Zhao D, Xie J, Wen H, Liu C, Li Y, Li W, Wang S. Deep learning for classifying the stages of periodontitis on dental images: a systematic review and meta-analysis. BMC Oral Health. 2023 Dec 19;23(1):1017.
61. Alfahmi RB. Awareness and Application of Artificial Intelligence Tools in Prosthodontic Treatment Planning Among Dental Students and Practitioners in Saudi Arabia. Asian Journal of Pharmaceutics (AJP). 2025;19(04).
62. 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.
63. Jayasheelan JA, Manju V, Deepthy SS, Saranya SK. Artificial intelligence and the future of prosthodontics: a narrative review. The Saudi Dental Journal. 2026 Jun;38(6):88.
64. Schwendicke F, Rahimi HM, Tichy A. Artificial intelligence in prosthodontics. Dental Clinics. 2025 Apr 1;69(2):315-26.
65. Cervino G, Peditto M, Portelli M, Militi A, Matarese G, Fiorillo L, Nucera R, Oteri G. The use of AI for prosthodontic restoration: Predictable and safer dentistry. Engineering Proceedings. 2023 Oct 26;56(1):68.
66. Syed N, Bibi H, Liaqat S. Artificial Intelligence and Digital Workflow Innovations in Prosthodontics. Pakistan Journal of Medical & Cardiological Review. 2026 Feb 2;5(1):504-13.
67. Del Hougne M, Del Hougne P, Di Lorenzo I, Höhne C, Schrenker J, Schmitter M. Toward artificial intelligence in dental prosthesis planning—a preliminary in-silico feasibility study. BMC Oral Health. 2025 Aug 31;25(1):1386.
68. Kaviandost P, Barkhordar S, Asghari M. Revolutionizing Dentistry: The Role of Artificial Intelligence in Diagnosis, Treatment Planning, and Patient Care. Saudi Journal of Oral & Dental Research. 2025;10(6):260.
69. Kadempour A, Wathanapong P, Cantatore A, Mirafzali S, Haku-Mizuhara K, Yamaguchi S. Artificial intelligence-driven workflow synchronizing interdisciplinary dentistry: Narrative review. Journal of Prosthodontic Research. 2026:JPR_D_25_00287.
70. Krastev T, Payer M, Krastev Z, Cardelles JF, Vegh A, Banyai D, Geczi Z, Vegh D. The utilisation of CAD/CAM technology amongst Austrian dentists: A pilot study. international dental journal. 2023 Jun 1;73(3):430-4.
71. Giuliodori G, Rappelli G, Aquilanti L. Intraoral scans of full dental arches: an in vitro measurement study of the accuracy of different intraoral scanners. International journal of environmental research and public health. 2023 Mar 8;20(6):4776.
72. Thurzo A, Strunga M, Havlínová R, Reháková K, Urban R, Surovková J, Kurilová V. Smartphone-based facial scanning as a viable tool for facially driven orthodontics?. Sensors. 2022 Oct 12;22(20):7752.
73. Saini RS, Alshoail HH, Kanji MA, Vaddamanu SK, Mosaddad SA, Heboyan A. Virtual articulator software: Accuracy, usability, and clinical applicability: A systematic review. International Dental Journal. 2025 Jun 1;75(3):1691-704.
74. Wang Q, Zhao Z, Zhou M, Zheng X, An N, Niu L, Tay FR, Ma C, Wang F. In vivo evaluation of the reliability and validity of three digital occlusion analysis methods. Journal of Dentistry. 2022 Dec 1;127:104355.
75. Dolatabadi R, Mohammadi A, Walker RB. A novel three-dimensional printed device with conductive elements for electromembrane extraction combined with high-performance liquid chromatography and ultraviolet detector. Journal of Separation Science. 2022 Aug;45(16):3187-96.
76. Valizadeh S, Fatahi Valilai O, Houshmand M. Allocation and scheduling of digital dentistry services in a dental cloud manufacturing system. International Journal of Computer Integrated Manufacturing. 2022 Jun 3;35(6):645-61.
77. Ouanes K, Farhah N. Effectiveness of artificial intelligence (AI) in clinical decision support systems and care delivery. Journal of medical systems. 2024 Aug 12;48(1):74.
78. GODHANI HK. Digital and Biomimetic Dentistry: The Future of Precision Oral Rehabilitation. ECLEARNIX EdTech Private Limited; 2026 Apr 3.
79. Alaoffey AS, Asiri MA, Alhazmi TA, Alshetaiwi AA, Almobarak AM, Alqasir YH, Algazlan SA, Alouf HS, Zakri HH, Al-Amri FG, Alshammari AH. Digital dentistry: transforming diagnosis and treatment planning through CAD/CAM and 3D printing.

Egyptian Journal of Chemistry. 2024 Dec 1;67(13):1177-90.

80. Prott LS, Atria PJ, Maluf CV, Blatz MB, Conejo J. In vitro comparison between complete arch abutment-level implant impressions with photogrammetry, grammetry, and intraoral scanning. The Journal of Prosthetic Dentistry. 2025 May 21.
81. Morsy N, El Kateb M. In vivo precision of digital static interocclusal registration for full arch and quadrant arch scans: a randomized controlled clinical trial. BMC Oral Health. 2022 Dec 1;22(1):559.
82. Iwauchi Y, Tanaka S, Kamimura-Sugimura E, Baba K. Clinical evaluation of the precision of interocclusal registration by using digital and conventional techniques. The Journal of Prosthetic Dentistry. 2022 Oct 1;128(4):611-7.

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