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# Application and Accuracy of Artificial Intelligence in Prosthodontics: A Systematic Review

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**Abstract**

Missing teeth or facial differences often need careful treatment. Yet fixing them usually means long hours shaping by hand plus guesswork during checks. Now machines that learn from data are changing how dentists plan care - making steps quicker while improving fit and feel. A close look at recent work explores how well these smart systems perform when spotting issues, crafting solutions, or building replacements. Rules like PRISMA and PICO helped narrow results found in major research hubs - PubMed among them - until just ten solid examples remained under study. Each one tested tech tools made for real-world dental tasks without skipping key standards. One study spotted AI models hitting marks between 93.8% and 98% when telling apart dental implant types. Software powered by artificial intelligence cuts down how long it takes to shape crowns - while still catching margins right 97.43% of the time. Instead of guessing, predictive tools reached 98.5% precision predicting if CAD/CAM crowns might loosen later. Where human eyes struggle with color choices or small mistakes in shaping, machines step in quietly but sharply. Yet despite promise, many dentists hesitate - mainly because inner workings of certain programs stay hidden. Long runs through real clinics haven't happened enough yet either.

**Keywords**: Artificial Intelligence, Prosthodontics, Machine Learning, Deep Learning, Digital Workflow, Dental Implants.

## Introduction

Artificial intelligence (AI) is the ability of computer systems and software algorithms to perform tasks that require human intelligence. These tasks include problem-solving , logical reasoning , and learning from data .[4,5,9]. The two principal branches of AI used in the medical and dental fields are machine learning (ML), which applies statistical models to identify patterns, and deep learning (DL), which uses multi-layered neural networks to interpret complex high-dimensional data such as three-dimensional scans and radiographs[7,8,9]. These technologies have led to a new paradigm in healthcare, enabling more accurate diagnoses and personalized treatment plans.[4,5,10]

Prosthodontics is a complex and diverse specialty that deals with the rehabilitation of patients with missing teeth and deformities of the head and neck due to congenital variations, trauma or disease[4,5]. This field has traditionally depended on labour-intensive analogue procedures such as elastomeric impressions, stone casts and manual laboratory techniques that are highly dependent on the manual skills and subjective interpretation of clinicians and technicians. However, the demand for increased precision and patient comfort has gradually led to a shift to digital workflows including intraoral scanning, computer-aided design and manufacture (CAD/CAM) and additive manufacturing (3D printing)[8].

Now, AI is being integrated into these digital workflows to enhance clinical decision-making and automate repetitive tasks[5,8,9]. Artificial Intelligence (AI) technologies have been incorporated in prosthodontics for margin detection, evaluation of occlusal options, tooth shade selection, and CAD-CAM crown design[7,8]. While having the potential to introduce clinical routine and standardization of the treatment, they allow for individualized and patient-oriented course of action as well.[5,7].

Artificial intelligence (AI) may be able to yield highly favourable outcomes on selected tasks. A study demonstrates that such systems are capable of identifying dental implant systems from radiographs with up to a 98% rate of accuracy[2]. Artificial intelligence approaches for caries detection, partially dentate classification and prediction of the probability of debonding of CAD/CAM dental crowns are highly efficient[5,7]. Artificial intelligence techniques have been applied in maxillofacial rehabilitation to virtually model the human external ear (auricle) and to predict changes in facial soft tissues resulting from the wear of complete dentures using current or proposed dental appliances[4,7].

The role of AI in the incorporation of artificial intelligence to the current prosthodontic digital workflows. The role of AI in the incorporation of artificial intelligence to the current prosthodontic digital workflows. Prosthetic planning is a mathematically complex process that has thousands of possible clinical variables that clinicians manually interpret to determine the best clinical solution for each patient. When all these parameters are considered, there is the potential for significant cumulative error and variability among clinicians. However, AI systems have the potential to reduce variables such as these and provide an objective and reliable analysis. Although AI is being integrated into the medical field at a rapid pace, its incorporation into prosthodontics has been slow, primarily because of the variability of individual cases.

To evaluate performance and reliability of current models prior to their integration into clinical practice, and to provide evidence-based clinical pathway for safe and ethical use of AI in modern prosthodontic practice. A comprehensive review of current literature on

experimental studies, limitations of the studies, clinical needs, and their evaluation. Most studies have shown preliminary experimental results of high performance; however, they need long-term clinical validation. This article provides a basis for critical evaluation of current studies, discusses limitations, and highlights clinical needs for the use of AI systems in clinical practice. This review article aims to provide a thoughtful, critical, and evidence-based clinical pathway for safe and ethical use of AI in prosthodontic practice.

**Key reasons for conducting the study:**

- To evaluate the performance of growing AI models in implant type recognition, success prediction, and design optimization.
- To address the limitations of human subjective judgment in complex diagnostic tasks like shade matching and margin detection.
- To investigate the time efficiency and accuracy of AI-assisted crown design compared to traditional CAD/CAM and manual methods.
- To identify knowledge gaps and ethical concerns regarding data privacy and the scarcity of high-quality dental datasets.
- To educate dental practitioners on the evolving technological approaches and their practical clinical importance.

**Objectives**

- To assess the diagnostic performance and accuracy of AI models in the identification and classification of dental implant systems.
- To evaluate the efficacy of AI in digital prosthodontic design, specifically for margin extraction, occlusal surface reconstruction, and RPD framework design.
- To compare the occlusal accuracy and fabrication time of AI-designed restorations with those produced via traditional CAD methods.
- To investigate AI's role in outcome prediction, such as forecasting implant success rates and soft-tissue aesthetic changes.
- To explore the applications of AI in maxillofacial prosthodontics, including pigment recipe prediction and the fabrication of auricular prostheses.
- To examine the limitations and future prospects of AI-driven digital workflows in promoting patient-centred, individualized prosthodontic treatment.

**Material and Methods**

This systematic review was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. A systematic review protocol was published using the PICO (Population, Intervention, Comparison, and Outcome) framework. The purpose of this systematic review was to assess the available evidence regarding the accuracy and diagnostic performance of AI-based models in different workflows (fixed, removable and implant-supported dentistry and their combinations) in prosthodontics.

**Inclusion criteria**

Studies were selected for inclusion if they met the following criteria:

- **Study Design:** Peer-reviewed original research, clinical trials, in vitro studies, and case series involving at least five cases.
- **Population:** Patients requiring prosthodontic rehabilitation, including those with missing teeth, craniofacial defects, or indications for crowns, bridges, and dentures.
- **Intervention:** Application of artificial intelligence (AI), machine learning (ML), or deep learning (DL) algorithms for diagnosis, design, or fabrication.

- **Outcome:** Reporting of quantified performance metrics such as accuracy, sensitivity, specificity, area under the curve (AUC), or design time.
- **Language and Timeline:** Articles published in the English language within the last 10 to 20 years to capture modern digital advancements.

**Exclusion criteria**

The following were excluded from the review:

- **Type of Article:** Narrative reviews, letters to the editor, posters, and conference abstracts without full-text availability.
- **Methodology: Animal studies**, forensic studies, or research involving dental robotics not directly related to prosthetic design.
- **Scope:** Studies focused on other dental specialties such as endodontics or orthodontics unless they directly integrated with a prosthodontic workflow.
- **Data:** Research that failed to provide measurable numerical outcomes or specific details regarding the AI model used.

Table 1: PICO Guideline

| Component | Description |
|---|---|
| Population (P) | Patients with indications for prosthetic reconstructions or dental image datasets (radiographs, 3D scans). |
| Intervention (I) | Diagnostic or design models based on AI, Machine Learning, or Deep Learning algorithms. |
| Comparison (C) | Conventional methods (analogue), traditional CAD software, or human dental professionals. |
| Outcome (O) | Accuracy, precision, sensitivity, specificity, design time efficiency, and marginal fit. |

**Search method**

A comprehensive electronic search was conducted across major bibliographic databases, including PubMed/MEDLINE, EMBASE, Scopus, Web of Science, the Cochrane Library, and Google Scholar. The search syntax combined MeSH terms and free-text keywords using Boolean operators: ("Prosthodontics" OR "prosthetic treatment" OR "dental crown" OR "denture") AND ("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning" OR "Neural Networks"). Additional manual searches were performed in the reference lists of included studies and specific prosthodontic journals to ensure no relevant literature was overlooked.

**Study selection**

**PRISMA Flow Data**

- Total records identified: 156
- After duplicates removed: 80
- Screened: 42
- Full-text assessed: 22
- Included studies: 10

**Selection Process**

The search results were processed in different stages where two reviewers independently assessed the titles and abstracts of the included articles for inclusion or exclusion on the basis of the inclusion and exclusion criteria. Cases of disagreement during the screening or full-text assessment process were discussed and solved by consensus. If consensus could not be reached, a third senior reviewer was consulted.

**Data collection and data items**

**Data Items Collected**

The following items were extracted point-wise from the selected studies:

- **Study Characteristics:** Primary author, year of publication, country of origin, and study design.

- **Population/Data Features:** Total sample size, type of dental images used (e.g., panoramic radiographs, intraoral scans), and dataset split for training/validation.
- **AI Technical Details:** Specific AI model architecture (e.g., CNN, ANN, SVM, GAN), software used, and the branch of AI applied.
- **Application Area:** Focus of the AI (e.g., implant identification, crown design, shade matching, or margin detection).
- **Outcome Metrics:** Numerical values for accuracy, sensitivity, specificity, design time, and comparative results against human experts or traditional methods.

**Data Collection Process**

Data extraction was conducted by two reviewers using pre-designed Microsoft Excel templates. Assessment of the quality of included studies and the risk of bias were performed using either The Joanna Briggs Institute (JBI) Critical Appraisal Checklist for cross-sectional studies and The Cochrane Risk of Bias tool for randomised and non-randomised trials. The results were reported in a narrative or meta-analytic form where findings' data were homogeneous.

**Result**

The comprehensive electronic search across the provided sources involved the initial identification of tens of thousands of records. Databases utilized included PubMed/MEDLINE, Scopus, EMBASE, and Web of Science. Following the removal of duplicates and a rigorous multi-stage screening process based on titles, abstracts, and full-text eligibility, the final number of included articles within the review sources are 10 studies. The sources followed PRISMA or PICO guidelines to ensure systematic and transparent reporting.

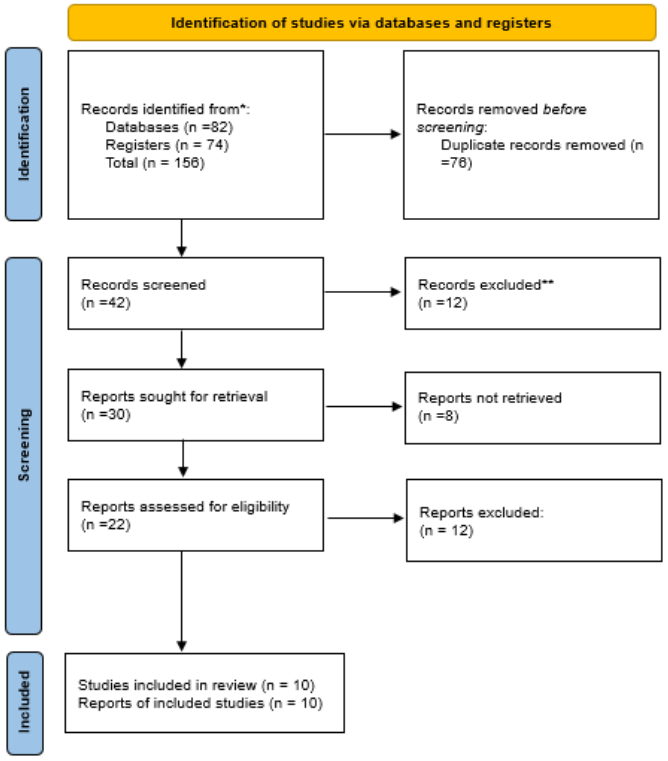


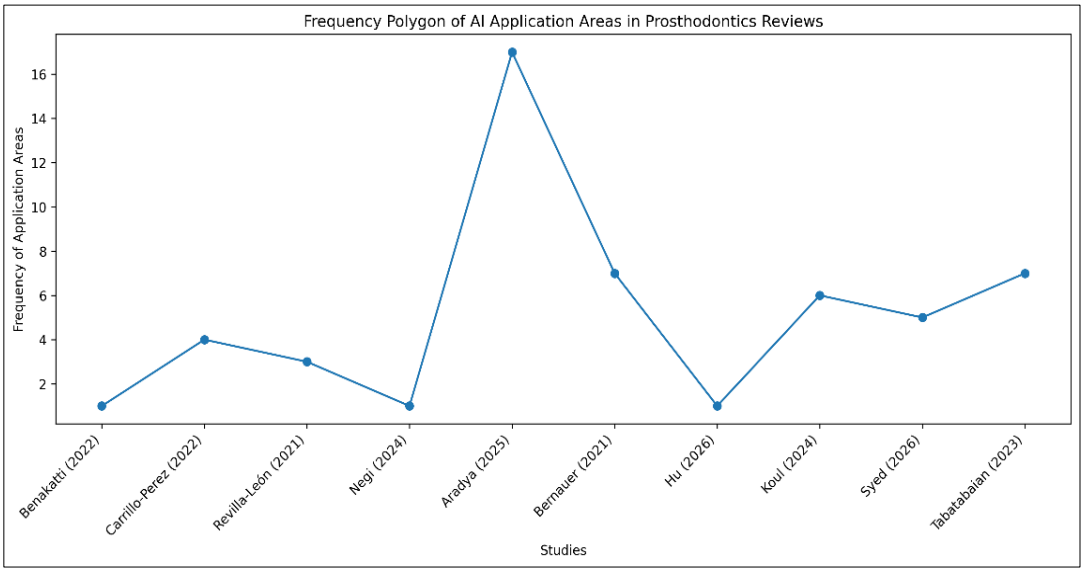

Table 2: Characteristics of included studies

The table below summarizes the key characteristics of the all studies, including study types, sample sizes, AI techniques, and primary outcomes.

| Author (Year) | Study Type | Sample Size | AI Technique Used | Application Area | Key Outcome |
|---|---|---|---|---|---|
| Benakatti (2022)[1] | Systematic Review & Meta-Analysis | 8 studies | KNN, CNN | Dental implant system identification | Pooled accuracy of 95.43% for implant recognition. |
| Revilla-León (2021)[2] | Systematic Review | 17 articles | CNN, SVM, Decision trees, | Implant identification, | Accuracy of 93.8%–98% for recognition; |

| | | | | | |
|---|---|---|---|---|---|
| | | | ANN | success, and design | 36.6% stress reduction in design. |
| Negi (2024)[3] | Umbrella Review | 7 SRs | Multilayer Perceptron, SVM, CNN | Dental caries diagnosis and detection | CNNs yielded higher accuracy, sensitivity, and specificity. |
| Aradya (2025)[4] | Scoping Review | 35 articles | DL, ML, DCGAN, LLMs (ChatGPT) | Maxillofacial prosthodontics | AI enhances imaging accuracy and genetic risk evaluation. |
| Bernauer (2021)[5] | Systematic Review | 7 studies | CNN, ANN, Intrinsic AI | Prosthodontic diagnostics and prediction | High performance for caries detection and debonding probability. |
| Hu (2026)[6] | Meta-Analysis | 12 articles | DL and CAD/CAM algorithms | Dental crown design | Shorter design time and better occlusal accuracy than traditional CAD. |
| Koul (2024)[7] | Narrative Review | 12 articles | CNN, ANN, SVM, BPNN | Diagnosis, shade, and outcome prediction | 98% diagnostic effectiveness for crowns on radiographs. |
| Syed (2026)[8] | Narrative Review | Literature search | ML, DL, Computer Vision | Digital workflow innovations | Enhanced precision and reproducibility of prosthetic restorations. |
| Tabatabaian (2023)[9] | Literature Review | 157 articles | ML, DL, Fuzzy Logic | Restorative dentistry (Caries/Margin/RPD) | Promising performance compared to traditional instrumental methods. |
| Carrillo-Perez (2022)[10] | Comprehensive Review | 120 papers | DL, Fuzzy Logic, ML (SVM, RF) | Esthetic dentistry and color research | Outstanding results in high-performance decision support systems. |

Figure 1: Distribution of AI Application




**Discussion**

The accuracy of several computer-aided systems based on artificial intelligence in the field of prosthodontics has been proven in experimental and clinical studies[1,2,5]. In particular, image diagnostics show a high performance. The use of convolutional neural networks (CNNs) for image diagnostics reached high accuracy levels. The systems of dental implant could be identified with accuracy of 93.8% to 98%, and the edentulous arches could be classified with accuracy up to 99.5%[1,7,10]. The high accuracy of the software is very useful to identify unknown implant parts when the information of implant is not available from the patient's medical record.[1,2].

Artificial Intelligence is changing the way dentists design restoratives digitally, offering a host of new features and automating many of the tasks that are typically carried out manually.[6,8]. Meta-analysis data shows that AI-powered software reduces dental crown design time while generating occlusal arch patterns which match the results from traditional CAD systems. AI design methods produce better occlusal results than human designers because AI systems can analyze intricate tooth shape data through advanced morphological pattern recognition. The system needs additional algorithmic development to reach natural tooth accuracy because it still depends on cusp angle measurements which need better optimization[6].

Automated margin detection represents another pivotal advancement, with AI models achieving up to 97.43% accuracy in identifying preparation finish lines[7,9,10]. The practice of manual margin tracing for indirect restorations has resulted in accumulating errors throughout its historical use, but current AI systems can now perform automatic tracing of subgingival margins with their high tracking performance[5,7,9]. The automation process improves crown and bridge marginal fit while reducing operator differences to produce consistent results across various medical environments[5,8].

Fuzzy logic (FL) and neural networks work together to solve the fundamental issues with tooth shade matching and color reproduction because of human judgment[9,10]. AI models have outperformed traditional visual methods by predicting precise pigment recipes for silicone prostheses and ceramic restorations which connects digital color representation to human color perception[4,7,10]. The systems provide essential support for

maxillofacial prosthodontics because they enable scientists to objectively assess the intricate translucent properties that human skin and ear structures exhibit[4].

AI helps predict treatment results which leads to improved personalized treatment strategies. The debonding probability models for CAD/CAM crowns achieve 98.5% accuracy in their predictions while other models can project post-surgery facial soft-tissue transformations that occur after complete denture implementation[2,5,7,10]. AI technology predicts genetic clefting risks and assesses alveolar bone grafting results which establishes a foundation for precision medicine in craniofacial research[4].

AI systems now control all manufacturing processes which begin with milling and 3D printing to achieve better material efficiency and stronger product development. The manufacturing systems which use AI technology can adapt their operational settings through continuous adjustments to tool-path design and layer thickness based on actual production feedback which results in high product consistency and decreased material loss. The real-time quality control algorithms can identify minor production errors and internal manufacturing defects which helps to improve digital processes while decreasing the need for additional medical remake procedures[8].

The present situation continues to face multiple restrictions together with ongoing ethical problems which remain unsolved. Many AI systems function as "black boxes" because their decision-making procedures remain hidden from doctors which creates problems for both responsibility determination and professional relationship trust8. The effectiveness of these models depends on their training datasets which need high-quality and diverse content; the absence of standardized reporting guidelines creates challenges for algorithm evaluation and patient population result generalization. The lack of extensive clinical trials combined with prolonged validation processes stands as the main obstacle which prevents organizations from adopting new technologies[1,2,8].

The future of AI in prosthodontics is all about cloud solutions of data and cooperation in a multidisciplinary mode[4,10]. The combination of clinical record data and genomic information and 3D imaging data will enable better predictive analytics which will create personalized treatment plans for patients[8,10]. AI will automate repetitive tasks but it will also improve diagnostic accuracy whereas the technology functions as a prosthodontist support system that protects their ability to make judgments and show compassion and handle difficult cases[4,7,8].

**Conclusion**

The systematic review demonstrates that artificial intelligence serves as a transformative technology for prosthodontics because it enables dentists to achieve accurate diagnostics and improved efficiency through digital workflows. The AI-driven systems maintain 95% accuracy in implant identification while they reduce the time needed for crown design, which enables businesses to use their technology to create standardized processes that improve patient-specific treatment options. The technology effectively addresses long-standing challenges in the field, including subjective shade matching, manual margin detection, and the prediction of prosthetic outcomes.

The complete adoption of artificial intelligence in clinical practice requires extended testing and development of standardized procedures used as validation benchmarks which will establish its validity as a standard medical tool. The persistent issues of data protection and algorithm discrimination and hidden operations of deep

learning systems need to be solved through scientific research conducted at multiple clinical institutions. AI functions as a supportive tool which enhances the dental professional's skills to deliver accurate and effective treatment based on research findings for prosthodontic restoration procedures.

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