

# Artificial Intelligence-Powered Tools and Clinical Decision Support Systems for Prosthodontic Treatments

AI Powered  
Tools and  
Clinical Decision  
for Prosthodontic  
Treatments

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## ABSTRACT

**Objective:** To provide a narrative overview of the applications, performance, and limitations of artificial intelligence (AI) diagnostic tools and clinical decision support systems (CDSS) in prosthodontics, spanning diagnosis, treatment planning, prosthesis design, and prognosis.

**Place and Duration of Study:** This study was conducted at the Department of Prosthodontics and Implantology, College of Dentistry, King Faisal University, Al-Ahsa, Saudi Arabia, from September 2025 to March 2026.

**Methods:** A narrative review of the literature was conducted, synthesising evidence from published systematic reviews, scoping reviews, diagnostic-accuracy studies, and clinical reports. PubMed, Scopus, Web of Science, Google Scholar, and Semantic Scholar were searched for English-language articles published between 2021 and 2026 using combinations of the terms “artificial intelligence,” “machine learning,” “deep learning,” “convolutional neural network,” “clinical decision support system,” “prosthodontics,” “fixed/removable prosthodontics,” “dental implant,” “maxillofacial prosthesis,” “tooth shade,” “occlusion,” and “digital smile design.” The review followed the Introduction-Methods-Results-Discussion structure commonly used for narrative reviews.

**Results:** AI diagnostic tools demonstrated high accuracy in image-based recognition tasks relevant to prosthodontics, including implant-system identification on radiographs and classification of partially edentulous arches, while performance in objective shade matching, margin detection, and multivariable prognosis was more modest. AI-assisted methodologies in treatment planning and prosthesis design have demonstrated clinically promising accuracy and significant workflow efficiencies. However, it is noteworthy that the majority of evidence supporting these findings originates from retrospective or simulation-based studies. CDSS, including case-based and rule-based systems, improved the consistency and evidence-basis of clinical decision-making, but real-world adoption, maturity, and clinician uptake remained limited. Persistent barriers included a lack of prospective validation, limited data standardisation, limited model interpretability, and ethical and regulatory concerns.

**Conclusion:** AI diagnostic tools and CDSS show considerable potential to enhance diagnostic precision, treatment planning, and prosthesis design in prosthodontics. However, current evidence is largely early-stage, and prospective clinical validation, transparent models, and clear regulatory frameworks are required before routine clinical adoption. AI is best positioned as an adjunct that supports, rather than replaces, the prosthodontist.

**Key Words:** Artificial intelligence; Deep learning; Prosthodontics; Clinical decision support systems; Digital dentistry; Prosthesis design

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## INTRODUCTION

Prosthodontics is the dental discipline concerned with the replacement of lost intraoral and extraoral structures.

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It also includes the restoration of partially or completely destroyed anatomical structures. This is achieved predominantly through prostheses, appliances, and restorations fabricated indirectly in the dental laboratory. This indirect, laboratory-based pathway distinguishes prosthodontics from restorative dentistry, in which restorations are fabricated directly at the chairside. The prosthodontic scope therefore includes fixed tooth- and implant-supported crowns and bridges, dental implants, removable complete and partial dentures, and maxillofacial prostheses. To deliver these predictably, the prosthodontist must diagnose and monitor tooth wear, occlusion, occlusal vertical dimension, facial esthetics, masticatory loading, and the broad range of patient-related factors that influence the design and longevity of a prosthesis.

Artificial intelligence (AI) refers to computational systems that perform tasks ordinarily requiring human intelligence. Within AI, machine learning (ML) enables systems to learn statistical patterns from data, while deep learning (DL) particularly convolutional neural networks (CNNs) has proven exceptionally capable in analysing images such as radiographs and intraoral scans<sup>1,3</sup>. Over the past two decades, AI has expanded across all dental specialities, with the majority of applications image-based and focused on diagnosis and decision support<sup>1,2,3</sup>. Prosthodontics is especially amenable to AI because its modern workflows are increasingly digital and generate large volumes of image and three-dimensional data well suited to pattern-recognition models<sup>2,4</sup>.

Two converging applications are reshaping the field: AI diagnostic tools, which interpret clinical and imaging data, and clinical decision support systems (CDSS), which provide clinicians with evidence-based recommendations at the point of care. This narrative review summarises the current applications and performance of AI diagnostic tools and CDSS across the prosthodontic workflow, and considers the principal challenges and future directions

## METHODS

A narrative review was undertaken to allow a broad synthesis across heterogeneous study designs. PubMed, Scopus, Web of Science, Google Scholar, and Semantic Scholar were searched for English-language articles published between 2021 and 2026. Search terms combined AI-related vocabulary (“artificial intelligence,” “machine learning,” “deep learning,” “convolutional neural network,” “clinical decision support system”) with prosthodontic vocabulary (“prosthodontics,” “fixed prosthodontics,” “removable prosthodontics,” “dental implant,” “maxillofacial prosthesis,” “tooth shade,” “occlusion,” “occlusal vertical dimension,” “digital smile design”) using the Boolean operators AND and OR. Systematic reviews, scoping reviews, diagnostic-accuracy studies, and representative clinical and technique reports relevant to prosthodontic diagnosis, treatment planning, prosthesis design, prognosis, and decision support were prioritised. Articles concerning AI applications outside prosthodontics, or lacking a description of the AI model or its performance, were not emphasised.

### AI Diagnostic Tools in Prosthodontics

#### Digital diagnosis and data capture

AI increasingly supports the diagnostic phase that precedes prosthetic treatment. Intraoral scanning and digital records can be analysed by AI to classify clinical situations and recognise anatomy. A CNN trained on intraoral occlusal images classified seven distinct maxillary prosthodontic scenarios, including dentate,

partially edentulous, edentulous, and various maxillectomy presentations, with test accuracies of 0.90 to 0.95 and area-under-the-curve values of 0.98 to 1.00, as a first step toward an automated diagnosis and prosthesis-design system<sup>13</sup>. In implant prosthodontics, a deep-learning object-detection model identified implant brands on periapical radiographs with very high precision and recall and outperformed clinicians across experience levels, although the authors noted the absence of external validation as a key limitation<sup>12</sup>. Scoping evidence confirms that AI and other digital applications are being applied chiefly to diagnostics and treatment planning, with virtual treatment simulation among the most frequent diagnostic uses<sup>9</sup>.

#### Occlusion, occlusal vertical dimension, and tooth wear

Accurate assessment of static and dynamic occlusion is central to prosthodontic diagnosis. Digital occlusion technologies, intraoral scanners, optical jaw-tracking systems incorporating AI algorithms, and computerised occlusal-analysis devices, now allow virtual articulation and analysis of occlusal contacts and mandibular motion, providing powerful diagnostic and design tools, though their accuracy for capturing static and dynamic occlusion requires further validation<sup>10</sup>.

#### Tooth shade selection and facial esthetics

Objective shade determination and esthetic analysis are long-standing prosthodontic challenges. A systematic review found intraoral scanners highly repeatable for shade matching and superior to visual selection, while still recommending visual verification of results<sup>11</sup>. AI-driven digital smile design (DSD) has advanced rapidly: a scoping review reported that AI-generated smile designs did not differ significantly from manually created designs in esthetic perception, with three-dimensional designs more accurate than two-dimensional ones<sup>19</sup>, and a systematic review and meta-analysis found AI-based DSD improved esthetic outcomes and yielded a pooled satisfaction prevalence of around 58%, albeit with moderate risk of bias<sup>20</sup>.

### AI in Treatment Planning, Prosthesis Design and Prognosis

#### Fixed and implant-supported treatment planning

AI has been applied extensively to implant planning. A systematic review with meta-analysis reported pooled accuracies of approximately 96% in the mandible and 83% in the maxilla for AI identification of edentulous areas and bone measurements on cone-beam computed tomography, while emphasising the need for further well-conducted studies<sup>15</sup>. A scoping review of AI in fixed tooth- and implant-supported prosthodontics found high accuracies (90–99.5%) for implant site detection and bone assessment, with prognostic models achieving over 90% accuracy in predicting implant

survival, but cautioned that most evidence remained early-stage and simulation-based <sup>7</sup>.

### Prosthesis design

AI is being used to automate and accelerate the design of indirect prostheses. A feasibility study using a generative adversarial network designed biomimetic single-molar restorations matched to natural teeth, demonstrating proof of concept while indicating that accuracy required further optimisation <sup>16</sup>. For removable prosthodontics, a CNN classified partially edentulous arches with accuracies of 99.5% (maxilla) and 99.7% (mandible) as the foundation of a removable partial denture (RPD) design system <sup>17</sup>. Systematic and narrative reviews confirm AI applications across automated restoration design, margin-line detection (accuracy approximately 90.6–97.4%), casting optimisation, prediction of facial changes in removable-prosthesis patients, and RPD design <sup>6,14</sup>, and contemporary digital-workflow reviews report promising AI performance in shade selection, automated tooth-anatomy design, and removable-prosthesis design <sup>8</sup>. In maxillofacial prosthodontics, a case-based reasoning system predicted definitive obturator designs for maxillectomy patients, with confidence scores correlating strongly with clinician-judged correct designs and a high precision among the most similar retrieved cases.<sup>18</sup>

### Prognosis and longevity

Beyond design, AI is being explored to predict prosthesis and implant outcomes. Reported prognostic models show promising but moderate performance, constrained by limited datasets and biological variability <sup>7,8</sup>, consistent with the broader observation that long-term outcome prediction remains less mature than image-recognition tasks <sup>5</sup>.

## CLINICAL DECISION SUPPORT SYSTEMS (CDSS) IN PROSTHODONTICS

Clinical decision support systems are platforms that provide clinicians with patient-specific, evidence-based recommendations at the point of care, increasingly powered by AI <sup>21,22</sup>. Several prosthodontic applications already function as decision-support tools: case-based reasoning for obturator design <sup>18</sup> and rule-based and CNN-driven expert systems for RPD design and education effectively encode expert knowledge to guide treatment planning <sup>6,17</sup>.

Evidence from medicine and dentistry indicates that AI-driven CDSS can improve diagnostic accuracy, optimise treatment selection, and reduce errors by delivering individualised recommendations <sup>21</sup>. A dental example demonstrated that integrating an electronic health record-based CDSS markedly increased appropriate clinical actions in routine practice <sup>24</sup>. Nevertheless, the maturity and real-world adoption of CDSS remain limited: a systematic review found that most CDSS rely on rule-based logic and rarely progress

beyond an early maturity level, with the decision “choice” and “implementation” phases underrepresented <sup>23</sup>, while reviews of CDSS more broadly highlight persistent challenges of data privacy, system integration, and clinician acceptance <sup>22</sup>.

## CHALLENGES, LIMITATIONS, AND ETHICAL CONSIDERATIONS

Despite strong technical performance, several barriers limit clinical translation. Most prosthodontic AI evidence derives from retrospective, simulation-based, or tightly controlled studies, and umbrella-level appraisal has found that many supporting systematic reviews are of low or critically low methodological quality, underscoring the scarcity of prospective validation <sup>5</sup>. Data limitations constrain model generalisability, and the “black-box” nature of deep-learning models challenges clinician trust and accountability. Ethical and regulatory concerns regarding bias, patient-data privacy, and liability remain unresolved and are recognised as critical to responsible adoption <sup>25</sup>. Workflow misalignment and limited clinician uptake further slow integration into daily prosthodontic practice <sup>22,23</sup>.

## FUTURE DIRECTIONS

The field is moving toward multimodal data integration, combining imaging with clinical and laboratory data, and toward generative, AI-assisted prosthesis design and individualised, prediction-based treatment planning <sup>4,8</sup>. Priorities for the coming years include the development of explainable and interpretable models, prospective clinical trials in diverse populations, robust regulatory frameworks addressing bias and privacy, and seamless point-of-care decision support embedded within existing digital workflows.

## CONCLUSION

AI diagnostic tools and clinical decision support systems are increasingly capable across the prosthodontic workflow, delivering high accuracy in image-based diagnosis and recognition, clinically promising performance in implant planning and prosthesis design, and meaningful gains in efficiency and consistency of decision-making. However, performance in objective shade matching and long-term prognosis is more modest, and the overall evidence base is still maturing, with limited prospective validation and unresolved ethical, regulatory, and integration challenges. At present, AI is best regarded as a complementary adjunct that augments the prosthodontist’s diagnostic and decision-making capacity rather than a substitute for clinical judgement, with its full potential contingent on rigorous validation and responsible implementation.

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