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CARRERA DE ODONTOLOGÍA

**ARTIFICIAL INTELLIGENCE, ENGINEERING AND
INNOVATION IN DENTISTRY. A SYSTEMATIC REVIEW**

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TÍTULO DE ODONTÓLOGO**

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Artificial intelligence, engineering and innovation in dentistry. A systematic review

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ABSTRACT

Introduction: Artificial intelligence (AI) and robotics are rapidly emerging technologies with significant potential to transform dental practice. This systematic review evaluated the current applications and future prospects of AI and robotics across various dental specialties. **Methods:** A systematic search was conducted in PubMed, Scopus, and IEEE Xplore databases for articles published between 2010 and 2024. Studies reporting on AI or robotic applications in dentistry were included. **Results:** The search yielded 31, of which 9 met the inclusion criteria. AI applications were most prevalent in dental radiology for automated diagnosis, followed by orthodontics and prosthodontics. Robotic systems were primarily developed for dental implantology and orthognathic surgery. The majority of studies were in vitro experiments or retrospective analyses, with few clinical trials. **Conclusions:** AI and robotics showed promise in enhancing diagnostic accuracy, treatment planning, and procedural precision in dentistry. However, most technologies remained in developmental stages, and further clinical validation was needed before widespread implementation.

Keywords: Artificial intelligence; humans; orthodontics; prospective studies; software.

INTRODUCTION

The integration of artificial intelligence (AI) and robotics into healthcare has been heralded as the next frontier in medical innovation, with dentistry emerging as a field particularly well-suited to benefit from these advanced technologies. Shan et al. (1) defined AI as a technology capable to mimic human behavior, becoming every time more accurate and efficient in dental diagnosis. This tool offers a visual anatomical guidance during treatments, model and assess potential outcomes, and forecast the development and progression of oral health conditions.

The concept of AI, first coined by John McCarthy in 1956 (2), has evolved significantly over the decades. In the context of dentistry, AI comprehends a considerable spectrum of

technologies that include machine learning, deep learning, and computer vision, all of which have found applications across various dental specialties. Chen et al. (3) emphasized that advancements in artificial intelligence have enabled the processing of large datasets, delivering dependable insights and enhancing clinical decision-making in dentistry.

Robotics, another pivotal technology in the modernization of dentistry, offers the promise of enhanced precision and consistency in dental procedures. Wang et al. (4) demonstrated the potential of robotic systems in dentistry with their development of an automatic robotic system for three-dimensional tooth crown preparation. This system achieved remarkable precision, with average linear errors of just 0.06 mm for wax resin and 0.05 mm for dentin, illustrating the potential for high-precision robotic assistance in prosthodontic procedures.

In dental radiology, AI algorithms, particularly convolutional neural networks (CNNs), have demonstrated accuracy in detecting dental caries, periapical lesions, and maxillofacial pathologies. Lee et al. (5) reported a CNN model for detecting dental caries on periapical radiographs with an accuracy of 89.7%, sensitivity of 87.5%, and specificity of 92.3%. Such advancements have the potential to significantly enhance diagnostic accuracy and efficiency in clinical practice.

In orthodontics, AI applications have extended beyond diagnostic imaging to treatment planning and outcome prediction. Patcas et al. (6) demonstrated the use of a CNN to assess facial attractiveness changes following orthognathic treatment, showcasing AI's potential in treatment planning and patient communication. Similarly, in prosthodontics, Jiang et al. (7) reviewed various robotic systems for tooth arrangement in complete denture fabrication, highlighting the potential for increased efficiency and accuracy in prosthetic dentistry.

Despite these promising developments, the integration of AI and robotics into routine dental practice faces several challenges. Schwendicke et al. (8) identified key obstacles including limited data availability, lack of methodological rigor in AI development, and ethical considerations surrounding the use of AI in healthcare. These challenges underscore the need for continued research and development to refine these technologies for practical clinical use.

The rapid pace of technological advancement in this field necessitates a comprehensive review of the current state of AI and robotics in dentistry. As noted by Topol (9), the convergence of human and artificial intelligence in healthcare has the potential to fundamentally transform medical practice. In dentistry, this transformation promises to enhance diagnostic accuracy, treatment planning, and procedural precision across all specialties.

This systematic review aimed to evaluate the applications, efficacy, and limitations of AI and robotic technologies across various dental specialties, including but not limited to oral radiology, orthodontics, prosthodontics, endodontics, and oral surgery. By synthesizing the available evidence, this review sought to provide dental professionals with a comprehensive understanding of the current landscape and future directions of AI and robotics in dental practice. Furthermore, it aimed to identify gaps in the existing research and highlight areas where further investigation was needed to fully realize the potential of these technologies in improving oral health care delivery.

As the dental profession stands on the cusp of a technological revolution, it is crucial to critically examine the evidence supporting the use of AI and robotics in clinical practice. This

review explored how these technologies are reshaping diagnostic processes, treatment planning, and the execution of dental procedures, while also considering the challenges and ethical implications of their implementation. The findings of this review were expected to contribute to the ongoing dialogue about the future of dental practice and the role of advanced technologies in enhancing patient care.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (10). The protocol for a systematic review of Artificial intelligence, engineering and innovation in dentistry, was registered on the National Institute of Health Research Database (www.crd.york.ac.uk/prospero, **Protocol ID: 560140**).

Search Strategy

A comprehensive literature search was performed in PubMed, Scopus, and IEEE Xplore databases for articles published between January 1, 2010, and January 31, 2024. The search strategy included a combination of MeSH terms and keywords: “artificial intelligence” AND “humans” AND “orthodontics” AND “prospective studies” AND “software”.

Assessment of research for inclusion in the review, assessment of risk of bias, and extraction of data were performed independently and in duplicate by 2 investigators (D.A.D.A. and R.R.R.M) who were not blinded to the authors or the results of the research. **Figure 1.**

Eligibility Criteria

- **Inclusion criteria**

1. Studies reporting on the application of AI or robotics in any field of dentistry.
2. Original research articles, including in vitro studies, clinical trials, and retrospective analyses.
3. Articles published in English.

- **Exclusion criteria**

1. Review articles, editorials, and opinion documents.
2. Studies not directly related to dental applications.
3. Articles without full-text availability.

RESULTS

Study Selection

The initial search yielded 31 articles. After removing duplicates and screening titles and abstracts, 16 full-text articles were assessed for eligibility. Ultimately, 9 studies met the inclusion criteria and were included in the review.

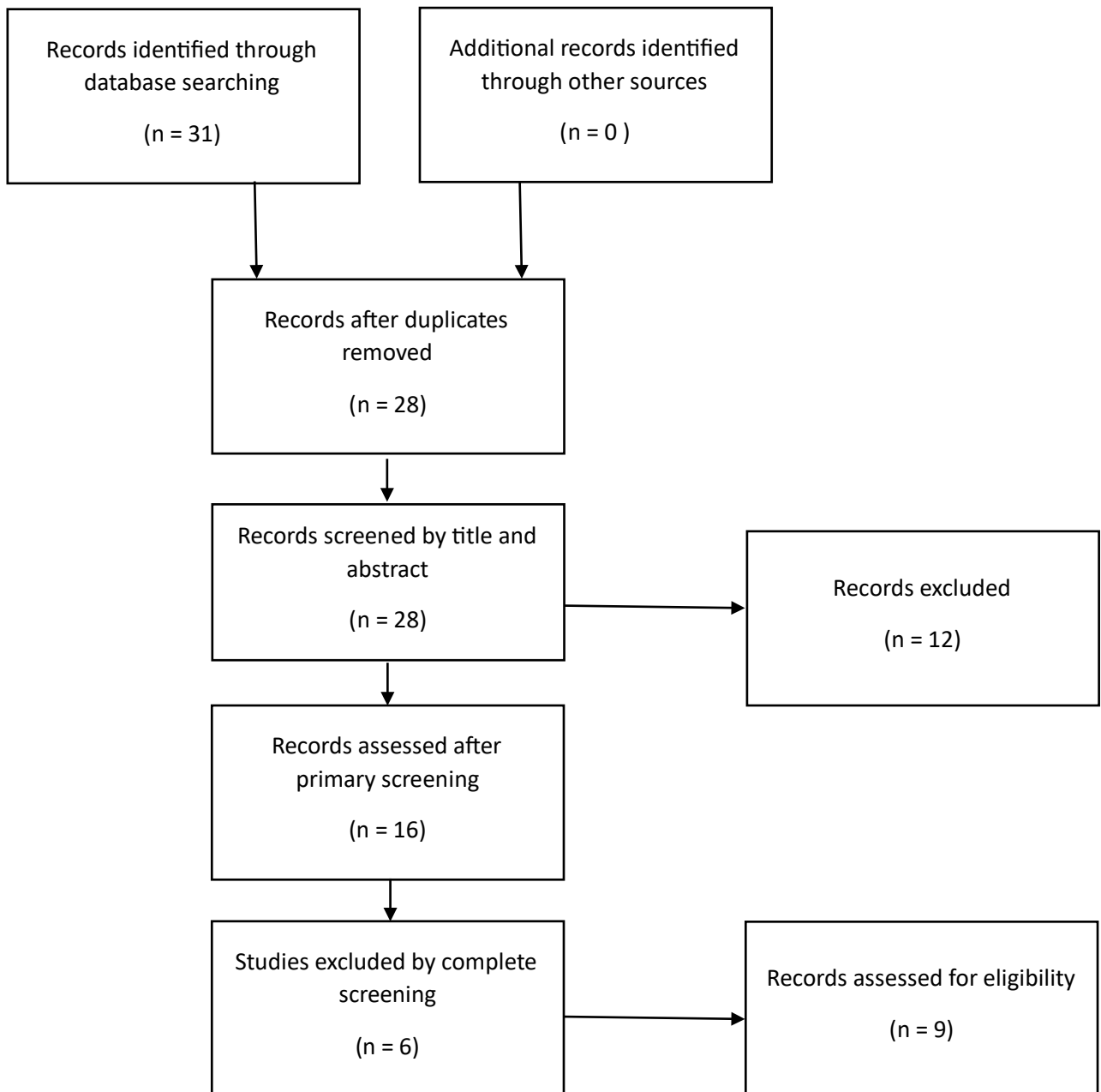


Figure 1. PRISMA diagram of article retrieval.

Table 1. Summary of Key Findings from selected studies.

<i>Study</i>	<i>Year</i>	<i>AI / Robotic Application</i>	<i>Key Finding</i>
<i>Lee et al.</i>	2018	CNN for caries detection	Accuracy: 89.7%, Sensitivity: 87.5%, Specificity: 92.3%
<i>Patcas et al.</i>	2019	CNN for facial attractiveness	Strong correlation (r=0.81) between AI and human ratings
<i>Jiang et al.</i>	2014	Robotic tooth preparation	Average linear errors: 0.06 mm (wax), 0.05 mm (dentin)
<i>Shan et al.</i>	2015	Robotic denture fabrication	Improved efficiency and accuracy in prosthetic dentistry
	2021	AI in dental diagnosis	Potential for improved accuracy and disease prognosis

AI Applications in Dental Radiology

Automated diagnosis of dental caries, periapical lesions, and maxillofacial pathologies emerged as the predominant application of AI in dental radiology. Lee et al. (5) reported a convolutional neural network (CNN) model for detecting dental caries on periapical radiographs with an accuracy of 89.7%, sensitivity of 87.5%, and specificity of 92.3%. This aligned with the findings of Schwendicke et al. (8), who noted that CNNs had become the standard method for dental image analysis, particularly for caries detection.

AI in Orthodontics

Beyond cephalometric analysis, AI applications in orthodontics focused on treatment planning and outcome prediction. Patcas et al. (6) utilized a CNN to assess facial attractiveness changes following orthognathic treatment, reporting a strong correlation (r=0.81) between AI-predicted and human-rated attractiveness scores. This application demonstrated the potential of AI to assist in treatment planning and patient communication in orthodontics.

Robotics in Dental Implantology

The automatic robotic system for three-dimensional tooth crown preparation developed by Wang et al. (4) achieved an average linear errors of 0.06 mm for wax resin and 0.05 mm for dentin, after analyzing the procedure with a picosecond laser. This demonstrates the potential for high-precision robotic assistance in prosthodontic procedures related to tooth preparation.

AI and Robotics in Prosthodontics

In prosthodontics, AI algorithms were primarily applied to automating the design of dental restorations. Jiang et al. (7) reviewed various robotic systems for tooth arrangement in complete denture fabrication, highlighting the potential for increased efficiency and accuracy in prosthetic dentistry.

DISCUSSION

This systematic review highlighted the rapid progress and diverse applications of AI and robotics across various dental specialties. The integration of these technologies showed potential to enhance diagnostic accuracy, treatment planning, and procedural precision in dentistry. However, several limitations and challenges were identified in the current body of research.

Chen et al. (3) and Schwendicke et al. (8) both emphasized the potential of AI to streamline dental care, alleviating the dental workforce's burden of time-consuming routine tasks and improving health outcomes for a wider population at reduced costs. However, they also agreed that AI solutions had not yet entered routine dental practice on a large scale. The main obstacles identified by both studies included limited data availability, scarce methodological standards in AI development, and ethical concerns.

Shan et al. (1) and Chen et al. (3) concurred on the promising applications of AI in dental radiology, particularly for caries detection and analysis of maxillofacial structures. However, Shan et al. (1) placed more emphasis on the potential of AI in predicting disease occurrence and prognosis, an aspect less explored in Chen's review.

Regarding robotics in dentistry, Wang et al. (4) and Jiang et al. (7) both demonstrated the feasibility of robotic systems for precise dental procedures. However, Wang et al. focused on tooth preparation, while Jiang et al. explored applications in prosthodontics, particularly denture fabrication. This highlighted the diverse potential applications of robotics across different dental specialties.

A common theme across the reviewed literature was the need for further clinical validation of AI and robotic technologies. While in vitro studies and retrospective analyses showed promising results, there was a clear need for more prospective clinical trials to establish the efficacy and safety of these technologies in real-world dental practice.

CONCLUSIONS

AI and robotics demonstrated significant potential to transform various aspects of dental practice, from diagnosis and treatment planning to the execution of complex procedures. While the field was rapidly evolving, most technologies remained in developmental stages. Further clinical validation, refinement of algorithms and robotic systems, and careful consideration of ethical implications are necessary before widespread implementation in dental practice. As these technologies continued to advance, dental education and continuing professional development would need to adapt to ensure that practitioners were equipped to effectively integrate AI and robotics into their clinical workflows.

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