

DIGITAL TRANSFORMATION IN PROSTHODONTICS: THE ROLE OF ARTIFICIAL INTELLIGENCE AND ROBOTICS

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ABSTRACT

Artificial intelligence (AI) and robotics are transforming modern prosthodontics by improving diagnostic precision, treatment planning, prosthesis fabrication, and clinical workflow efficiency. The integration of machine learning (ML), deep learning (DL), computer-aided design/computer-aided manufacturing (CAD/CAM), intraoral scanners, cone beam computed tomography (CBCT), and robotic-assisted systems has introduced a new era of digital prosthodontics. AI algorithms facilitate automated diagnosis, smile designing, implant planning, occlusal analysis, and prosthesis customization, while robotics enhances precision in implant placement, tooth preparation, and laboratory automation. Despite significant progress, challenges including ethical concerns, high cost, data security, and lack of standardized clinical validation remain barriers to widespread adoption. This review discusses the principles, applications, advantages, limitations, and future prospects of AI and robotics in prosthodontics.

Keywords: Artificial intelligence, robotics, prosthodontics, CAD/CAM, digital dentistry, machine learning, implantology.

INTRODUCTION

Prosthodontics has evolved considerably with advancements in digital dentistry. Traditional prosthodontic procedures are progressively being replaced by computer-assisted technologies that improve precision and efficiency. Artificial intelligence refers to computational systems capable of performing tasks that normally require human intelligence, including pattern recognition, prediction, and decision-making. Robotics involves programmable mechanical systems capable of executing clinical or laboratory procedures with high precision.¹

AI technologies such as machine learning and deep learning are increasingly used in prosthodontics for diagnosis, treatment planning, prosthesis design, and workflow optimization. Robotics complements AI by enabling automated clinical procedures including implant surgery and tooth preparation. The combination of AI and robotics has the potential to revolutionize patient-centered prosthodontic care.^{1,2}

ARTIFICIAL INTELLIGENCE IN PROSTHODONTICS^{2,3}

AI in Diagnosis and Treatment Planning

AI systems analyze radiographs, CBCT images, and intraoral scans to assist clinicians in diagnosis and treatment planning. Deep learning algorithms can detect edentulous spaces, classify prosthodontic conditions, and assess bone quality for implant-supported prostheses.

Applications include:

- Automated interpretation of CBCT images
- Identification of anatomical landmarks
- Detection of marginal bone loss
- Occlusal analysis
- Smile design prediction
- Virtual articulator simulations

AI-based diagnostic systems improve diagnostic consistency and reduce human error.

AI in Digital Impression and CAD/CAM

Digital impressions acquired through intraoral scanners are integrated with AI-driven CAD/CAM systems for designing crowns, bridges, removable dentures, and maxillofacial prostheses.

AI enhances CAD/CAM workflows by:

- Automating margin detection
- Designing occlusal morphology
- Predicting ideal tooth arrangement
- Improving fit and esthetics
- Reducing laboratory time

Recent AI-integrated software can automatically generate prosthetic designs with minimal operator input.

AI in Implant Prosthodontics

Implant prosthodontics has greatly benefited from AI

technologies. Machine learning models evaluate CBCT data and assist in:

- Implant site selection
- Bone density assessment
- Nerve mapping
- Surgical guide fabrication
- Predicting implant success rates

AI-supported navigation systems improve implant placement accuracy and reduce complications.

AI in Maxillofacial Prosthodontics

AI-based facial scanning and 3D printing technologies assist in designing facial prostheses for patients with craniofacial defects. Deep learning algorithms can reconstruct missing facial anatomy using mirrored facial datasets and predictive modeling.

Applications include:

- Auricular prosthesis design
- Orbital prosthesis fabrication
- Nasal prosthesis reconstruction
- Facial symmetry analysis

These technologies improve esthetics, patient comfort, and treatment efficiency.

ROBOTICS IN PROSTHODONTICS^{4,6}

Robotic Tooth Preparation

Robotic systems have been developed for automated tooth preparation with high precision and reproducibility. These systems use AI-guided navigation and real-time imaging to minimize preparation errors.

Advantages include:

- Uniform reduction
- Reduced iatrogenic damage
- Improved marginal accuracy
- Enhanced patient safety

Studies report preparation errors below clinically acceptable thresholds.

Robotic Implant Surgery

Robotic-assisted implant placement systems such as Yomi and Remebot improve surgical precision by combining preoperative planning with intraoperative guidance.

Benefits include:

- Accurate angulation
- Reduced deviation
- Minimally invasive surgery
- Improved prosthetic outcomes

Robotic implant surgery demonstrates superior precision compared with conventional freehand techniques.

Robotic Denture Fabrication

Automation in denture fabrication includes robotic tooth

arrangement and additive manufacturing techniques. AI algorithms determine optimal tooth positioning and occlusal relationships.

Robotic systems improve:

- Denture symmetry
- Occlusal balance
- Manufacturing consistency
- Laboratory productivity

Digital denture systems significantly reduce clinical appointments and fabrication time.

ADVANTAGES OF AI AND ROBOTICS IN PROSTHODONTICS

1. Enhanced diagnostic accuracy
2. Improved precision and reproducibility
3. Reduced chairside and laboratory time
4. Better treatment predictability
5. Customized patient care
6. Increased workflow efficiency
7. Reduced human error
8. Improved patient satisfaction

AI-driven systems support evidence-based clinical decision-making and improve interdisciplinary collaboration.⁷

LIMITATIONS AND CHALLENGES

Despite promising advancements, several limitations exist:

- High initial investment cost
- Need for technical expertise
- Limited long-term clinical evidence
- Ethical and legal concerns
- Data privacy and cybersecurity issues
- Dependence on high-quality datasets
- Potential algorithmic bias

Clinical acceptance also depends on regulatory approval and integration into existing workflows.^{8,9}

FUTURE PERSPECTIVES

The future of prosthodontics is expected to involve fully integrated digital ecosystems combining AI, robotics, augmented reality, and 3D printing. Autonomous robotic procedures, intelligent prosthesis design, and predictive analytics may further enhance personalized treatment.¹⁰

Future developments may include:

- Real-time AI-assisted clinical decision systems
- Autonomous prosthesis fabrication
- Smart prostheses with embedded sensors
- AI-guided patient monitoring
- Cloud-based collaborative treatment planning

Although complete replacement of clinicians is unlikely, AI and robotics will continue to augment prosthodontic practice

and improve patient outcomes.

CONCLUSION

Artificial intelligence and robotics are reshaping contemporary prosthodontics through enhanced diagnostic capability, precise treatment planning, and automated clinical and laboratory procedures. AI-supported digital workflows improve efficiency, accuracy, and patient-centered care, while robotics enhances surgical precision and prosthesis fabrication. Despite challenges related to cost, ethics, and clinical validation, ongoing technological advancements suggest that AI and robotics will become integral components of future prosthodontic practice.

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