

Dentronics: Robotics and Artificial Intelligence in Dentistry

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Abstract

This article explores robotics and artificial intelligence (AI) in dentistry and their impact on patient care and treatment outcomes. AI and robotics have revolutionized dentistry by improving diagnosis, treatment planning, and execution of dental procedures. AI algorithms analyze patient data to assist dentists in making informed decisions. Robotics provides precise execution of procedures surpassing human capabilities. The integration of AI and robotics in dentistry revolutionizes oral health care. It optimizes treatment workflows, enhances patient experience, and achieves better treatment outcomes. AI-powered systems learn from patient data, enabling dentists to provide evidence-based care. This article highlights the current state of AI and robotics in dentistry, their applications, benefits, and challenges. It provides insights into how these technologies shape dentistry's future, leading to improved oral health care worldwide.

Keywords: Algorithms analyze, Artificial intelligence, Dental Nano-robots, Dental robotics, Endo micro-robot.

INTRODUCTION

Artificial intelligence (AI) and robotics have brought transformative advancements to various industries, and dentistry is no exception. The integration of AI and robotics in dentistry offers new possibilities for enhancing patient care, improving diagnostic accuracy, and streamlining dental procedures. These innovative technologies have the potential to revolutionize the field of dentistry, making it more efficient, precise, and patient-centric.^[1]

AI involves the development of intelligent machines capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, and decision-making. In dentistry, AI algorithms can analyze vast amounts of dental data, including patient records, radiographs, and treatment outcomes, to extract valuable insights and assist in diagnosis and treatment planning.

Meanwhile, robotics has emerged as a powerful tool in dentistry, enabling precise and consistent execution of dental procedures. They can assist dentists in various procedures, including dental implant placement, tooth preparation, and orthodontic adjustments, resulting in improved outcomes and reduced margin for error.^[2]

The synergy between AI and robotics in dentistry has the potential to revolutionize the delivery of oral health care. By combining AI's analytical capabilities with robotics' precision

and reliability, dentists can optimize treatment workflows, enhance patient experience, and achieve better treatment outcomes. In addition, AI-powered systems can continuously learn from patient data and feedback, enabling dentists to stay updated with the latest advancements in the field and provide evidence-based care.

However, the integration of AI and robotics in dentistry also raises ethical and regulatory concerns. Issues such as data privacy, security, and the potential replacement of human dentists by AI systems need to be addressed to ensure responsible and safe implementation of these technologies.

This paper aims to explore the current state of AI and robotics in dentistry, highlighting their potential applications, benefits, and challenges. By examining the latest research and developments in this field, one can gain valuable insights into how AI and robotics are shaping the future of dentistry, ultimately leading to improved oral health care for patients worldwide.

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Received: Sep. 12, 2023; **Accepted:** Oct. 17, 2023; **Published:** Oct. 30, 2023

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How to cite this article: Somkuwar K, Khare A, Saxena A, Joseph A, Sahni Y, Singh SM. Dentronics: Robotics and Artificial Intelligence in Dentistry. J Res Adv Dent 2023;14(6):xx.

Access this article online

Website:
www.jrad.co.in

DOI:
<https://doi.org/10.53064/jrad.2022.14.6.440>

The search strategy summary

Items	Specification
Date of search	July 6 th , 2023
Databases and other sources searched	Google search
Data Search Years	2001–2023
Search terms used	“Robotic dental application,” “Robotic surgery,” “Artificial intelligence in dentistry,” and “AI and Robotics Application in Dentistry”
Any additional considerations, if applicable	This paper adopts the format of a narrative review, as an unsystematic review, to provide a comprehensive narrative synthesis of the existing information and our own experiences. In accordance with the Narrative Review present this article to ensure a structured and informative presentation of the topic.

ROBOTICS

Is a field of technology that focuses on the design, construction, operation, and practical applications of robots, including their control systems and information processing capabilities. In the domain of dentistry, robotics has made significant advancements and has found diverse applications that contribute to improving dental procedures and training. Let us delve into some of these applications:

Dental patient robots

Realistic robots, such as Showa Hanako, Geminoid DK, and Simroid, have been specifically developed to simulate patient gestures and responses. These sophisticated robots enable dental students to gain practical experience by working with simulated patients. By interacting with these robots, students can practice various dental procedures and develop essential skills, enhancing their training and preparing them for real-life patient encounters.^[1]

Endo micro-robot

The field of endodontics, which focuses on treating dental pulp and root canal infections, has benefited from advanced computer-assisted technology. The endo micro-robot is an innovative device that automates several essential steps of endodontic procedures. Equipped with precise drilling mechanisms, cleaning tools, shaping capabilities, and three-dimensional filling systems, this robot significantly enhances the precision and efficiency of root canal treatments.^[3]

Nano-robots

Nano-robots, constructed using nanomaterials, have revolutionized several aspects of dentistry. These tiny robots utilize nanotechnology to provide fast and highly precise dental treatments. Nano-robots have been developed for various dental procedures, including cavity preparation, restoration of damaged teeth, treatment of dentine hypersensitivity, localized anesthesia delivery, single-visit orthodontic realignment, and tooth repair. With their miniature size, these robots can access hard-to-reach areas within the oral cavity, enabling more effective and minimally invasive treatments.^[4]

Maxillofacial surgical robots

The da Vinci robot, initially introduced in 2005 for maxillofacial surgery, received FDA approval in 2009. At present, the da Vinci robot is extensively utilized in nearly all surgical procedures conducted within the head and neck region.^[3] Robotic oral and maxillofacial surgery has become an attractive possibility, especially in the treatment of oropharyngeal carcinoma.^[5]

Implant surgeries

In 2017, a remarkable milestone in the field of dentistry was achieved in China when a robot dentist successfully performed the first autonomous implant surgery. In the field of dental surgery, robotic systems like “Yomi” FDA approved have been introduced to assist with implant placement procedures. This groundbreaking procedure involved the fitting of two teeth into a woman’s mouth. The development of robot dentists aimed to address two major challenges in the field: a shortage of qualified human dentists and the reduction of surgical errors. The robotic system utilized in the autonomous implant surgery was designed with advanced capabilities and precision. It consisted of a robotic arm equipped with sensors, cameras, and robotic tools specifically tailored for dental procedures. The sophisticated sensors allowed the robot to gather real-time data about the patient’s oral cavity, enabling it to accurately determine the location, angle, and depth for implant placement. Before the surgery, the patient underwent a comprehensive examination, including imaging scans, to provide the robot dentist with a detailed map of the oral structure. This information served as a guide for the robot to plan the procedure, ensuring optimal placement of the implants. The planning phase involved the identification of the ideal positions for the implants based on the patient’s bone density, gum health, and facial esthetics.

During the surgery, the robot dentist demonstrated its ability to perform the procedure autonomously, with minimal human intervention. The robot executed the necessary incisions, prepared the implant sites, and precisely placed the dental implants. Throughout the process, the robot continuously monitored the progress, making adjustments if needed to ensure accurate implantation.^[6]

The tooth preparation robot

Is a sophisticated robotic system designed specifically for oral and dental procedures. It comprises a robotic arm equipped with force sensors, motor actuators, and a dental hand-piece. This system allows for precise dental drilling operations and has undergone extensive *in vitro* testing.^[7]

Hang *et al.* developed a dental treatment robotic system that enables a physician to control the robot arm remotely from a console, providing greater precision, and control during oral procedures. This innovation enhances the accuracy and effectiveness of dental treatments.^[8]

Otani *et al.* introduced an automated system for tooth preparation using the Tooth Preparation Robot. This robot

utilizes existing tooth models and completed preparation models to perform anterior veneer extracorporeal tooth preparation. This advanced technology ensures consistent and reliable tooth preparation based on established models.^[9]

The tooth-arrangement robot

Is a robotic system developed by Canadian scientists for the fabrication of complete dentures. It utilizes a DOF CRS robot as its main component. The system includes a variety of parts such as light-sensitive glue, a light source device, a denture base, control and motion planning, robot modulation software for arranging teeth, a core control system, a computer, an electromagnetic gripper, and the 6-DOF CRS robot.^[10]

The success of the tooth-arrangement multi-finger hand system is attributed to the use of micro-robots integrated into the MOTOMAN UP6 robot system. These micro-robots, along with a picosecond laser device, demonstrated a high level of precision in tooth preparation, meeting clinical requirements with an error margin of approximately 0.089 ± 0.026 mm.^[11,12]

Orthodontic archwire bending robots

MOTOMAN UP6: A robot used in orthodontic archwire bending, the MOTOMAN UP6 offers flexibility in bending complex archwire shapes. With its 6° of freedom, it fulfills the flexibility requirements for precise archwire bending.^[13]

LAMDA system: Developed by Alfredo Gilbert, the LAMDA system utilizes a robot to rapidly and accurately bend archwires in two planes. However, the system has limitations in its applications.^[14]

Cartesian-type archwire bending robot: This system uses a robot with multiple components for archwire bending. It includes mechanisms for support, posture control, rotation, and blocking. While it can bend larger angles and is easy to mass produce and control, its single-end actuator structure may not meet individual archwire bending requirements.^[15]

SureSmile: SureSmile is an all-digital system that combines 3D imaging, computer techniques, and robotics for customized fixed orthodontic appliances. Digital images of the patient's mouth are used for diagnostics and treatment planning. Robots grasp and bend the archwire according to the predetermined specifications.^[14]

AI

AI has made significant strides in the field of dentistry, transforming various aspects of dental practice. Let us delve into the specific advancements AI has brought to the field:

Patient management

The introduction of AI-powered virtual assistants has streamlined patient management tasks such as efficient appointment scheduling, delivering personalized experiences, analyzing vast amounts of patient data, aiding in accurate treatment planning, collecting and analyzing patients' dental history, managing insurance information, and even assisting with treatment planning based on the diagnosis. Moreover,

these virtual assistants can alert dental professionals about relevant patient health history and habits, empowering them to deliver personalized care that caters to individual needs.^[2]

Clinical decision support systems

AI-based clinical decision support systems have emerged as invaluable tools for dental professionals. By analyzing patient data, these systems assist in making clinical decisions, ranging from accurate diagnoses to treatment planning. Leveraging past clinical knowledge and utilizing machine learning algorithms, these systems help minimize human errors, resulting in faster and more precise diagnoses and treatment plans.^[16]

Radiology

AI applications leveraging convolutional neural networks have revolutionized the field of dental radiology. By analyzing dental images, these AI systems can efficiently detect and diagnose dental caries, aiding in the early detection, and treatment of dental problems. With AI's assistance, dental professionals can identify issues that may have otherwise gone unnoticed, leading to timely interventions.^[16]

Orthodontics

Artificial neural networks (ANNs) have proven to be immensely helpful in orthodontics. Orthodontists can utilize ANNs to determine whether teeth extraction is necessary as part of an orthodontic treatment plan. By leveraging patient data and machine learning algorithms, ANNs contribute to the development of personalized treatment plans tailored to the unique needs of each patient. This personalized approach improves treatment outcomes and patient satisfaction.^[17]

Detection of oral cancer

AI algorithms and image analysis techniques have significantly enhanced the early detection of oral cancer. Minimal invasive methods, such as brush biopsy, combined with AI concepts, enable accurate and efficient diagnosis using smartphone images. By leveraging advanced pattern recognition algorithms, AI systems can identify potential indicators of oral cancer, allowing for timely interventions and potentially saving lives.^[18]

While the integration of robotics and AI in dentistry offers significant benefits, it also raises several concerns that need to be addressed. Here are some of the key concerns associated with the use of robotics and AI in dentistry:

Ethical considerations

As with any advancement in technology, ethical concerns arise regarding the use of robotics and AI in dentistry. One major concern is the potential replacement of human dentists by robotic systems. While these technologies can enhance efficiency and precision, it is essential to strike a balance between human expertise and technological advancements to ensure optimal patient care.

Data privacy and security

The use of robotics and AI involves the collection, storage, and analysis of vast amounts of patient data. It is crucial to

address concerns related to data privacy and security to protect sensitive patient information from unauthorized access or breaches. Strict protocols and safeguards must be in place to ensure the secure handling of patient data.

Regulation and standards

The field of robotics and AI in dentistry is still relatively new, and there is a need for robust regulations and standards to govern their implementation. Clear guidelines should be established to ensure the safe and effective use of these technologies, including standards for quality assurance, system validation, and operator training.

Limited human touch and interaction

Dentistry is not only about clinical procedures but also involves human interaction and communication. The use of robotic systems may reduce the direct human touch and personal connection between dentists and patients. Maintaining a balance between technological advancements and preserving the patient–dentist relationship is crucial for holistic patient care.

Reliability and error management

While robotics and AI offer increased precision, there is always a risk of technical failures or errors. Robotic systems and AI algorithms need to be thoroughly tested, validated and regularly maintained to ensure their reliability. In addition, protocols should be in place to handle errors or malfunctions promptly and efficiently to minimize any potential harm to patients.

Accessibility and affordability

One concern is the accessibility and affordability of robotics and AI technologies in dentistry. These advancements can be expensive to implement, making them less accessible to smaller dental practices or underserved areas. Efforts should be made to ensure equitable access to these technologies, keeping in mind the varying resources and needs of different dental settings.

Impact on dental professionals

The integration of robotics and AI in dentistry may require dental professionals to adapt and acquire new skills. Training and education programs should be implemented to equip dentists and dental staff with the necessary knowledge and competencies to effectively utilize these technologies. The potential impact on the workforce should also be carefully considered to ensure a smooth transition and the preservation of job opportunities.

Addressing these concerns through careful planning, regulation, and ethical considerations can help maximize the benefits of robotics and AI in dentistry while ensuring responsible and patient-centered implementation.

CONCLUSION

The integration of AI in dentistry has brought significant advancements that are transforming the field. These AI

technologies have streamlined patient management tasks and provided valuable support in clinical decision-making processes. As a result, patient care has improved, diagnostic accuracy has been enhanced, and treatment approaches have become more personalized.

Similarly, the integration of robotics in dentistry has opened up new possibilities for better patient care. It has facilitated improved training for dental students and increased the accuracy and efficiency of various dental procedures. The use of robotics in dentistry has the potential to shape the future of the field by offering innovative tools and techniques that benefit both dental professionals and patients.

However, to fully realize the potential of robotics and AI in dentistry, certain challenges need to be addressed. These challenges include dealing with complex systems, managing the costs associated with setup and maintenance, improving training models, and mitigating data biases. In addition, efforts should be made to improve the applicability of AI outcomes in dentistry.

Successfully implementing robotics and AI in dentistry requires addressing these challenges and ensuring secure and efficient sharing and management of clinical data. By overcoming these obstacles, we can create a promising future where robotics and AI play a transformative role in enhancing dental care.

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