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Review Article

# AI-DENTBOTS- A Future Perspective of Dentistry-Narrative Review

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## Abstract

Dentistry is one of the revolutionize field in the era of artificial intelligence. We have our day-to-day treatment aspects starting from proper case history, radiographs as well as diagnostic procedures followed by treatment procedures. Artificial intelligence are nowadays trending in giving patient appointments, diagnostic decision making and treatment perspectives like robotic surgeries. Another enlightening future perspective are man made robots becoming most useful in medical field which were keeping their first step into dentistry. Application of robots have advantage of avoiding procedural errors, working time is minimised, efficacy of doing procedures are precise. Using artificial intelligence along with robotic technology in the field of dentistry make much more advancements leads to new innovations in the treatment aspects of oral diseases, biopsy, surgery, orthodontic treatments, radiographic procedures and diagnostic steps. we will review as narrative in this article from origin of robotics with artificial intelligence upto date informations spread like web in the field of dentistry.

**Keywords:** Artificial Intelligence, Artificial Neural Networks, Text to Speech, Virtual Reality

## Introduction

Robots were invented as a part of industry revolution and they were a part of supportive hands with human work forces, robotic application in dental field initiated since 1967 by Jenkins [1] in dental clinics we can replace as dental assistant as smart robots that can be used in cleaning dental instruments, assisting patients in appointments, giving dental education to patients before procedures, post operative instructions. This type of works were feeded to robots using artificial intelligence. Stepping stone of future combinations of robotics and artificial intelligence are manifold. The most important one is to build a work chain that join hands to all important assets such as safety of humans, human-centered interaction, human-robot interaction, reliablity and initiate to use manipulation skills, which can be employed on a large scale with specific initial use-cases [1]. Creating on this ideas we brief out the technological advancements that have been made which enable the use of robotic technology in dental field. Furthermore, we begin this steps by explaining the opportunities that emerge from a combination of robotics, artificial intelligence, machine learning and dentistry.

### Human-robot communication

The knowledge, planning, and estimation of robotic technology for use by or with humans is referred to as human-robot communication. There are various communication techniques between humans and robots. Physical human–robot interaction (pHRI) has become increasingly relevant in modern robotics and will also play an important role in AI-DENTBOTS applications. A former review article found haptics to be one of the key elements for robotics in dentistry [2]. Safe pHRI requires collaborative and sensitive robots and suitable compliant behavior made possible by appropriate controllers as described above. An example for physical communication between humans and robots are technical gestures [2]. They allow the human to relay context-dependent intentions to the robot by touching it. The robot's estimation of external forces can then process amplitude, direction and duration as well as other technical signals of the touch and use it as a means of communication. Extensions with machine-learning-based data analysis even allow autonomous contact classification. In a broader context, button interfaces are also related to physical interaction, especially if they are mounted on the robot in order to form an integrated direct control as for example on the Franka Emika Panda arm or the Baxter platform [3]. Another rather basic form of contact-based interaction are graphical interfaces such as where it is important to not overwhelm the user with information but focus on the current context. However, these methods may not be as intuitive as direct physical interaction with the robot. Contact-free interaction modalities like visual interaction based on RGB-D camera systems or similar technologies such as infrared have been researched for many years [3].

Especially, in dental scenarios this would be a great benefit as the dentist most of the time cannot move around freely to interact with a robot directly. In order to establish such type of communication, visually recognizable gestures like waving, hand opening/closing or pointing are utilized [4]. Visual communication is under the assumption that the dentist can move hands but cannot move around to directly touch the robot and after short auditory/visual cues for commands the dentist has hands free while the robot does its work autonomously. Furthermore, voice recognition and foot-pedal controlled commands are possible [4]. More advanced techniques involve motion tracking of humans or face recognition. Its advantages are that no direct contact with the robot is necessary and a certain degree of comfort for the human user is created since they do not have to alter their respective location. Despite major advantages over the last years, the systems are still sensitive to factors such as different lighting, obstacles and still require substantial computational resources [5]. Auditory communication including verbal communication and general sound signals to relay knowledge between humans and robots.

Signals with Simple sound are often feedback to help other means of communication e.g. when pressing buttons or performing a technical gesture a confirmation sound is produced. Verbal communication requires much more advanced algorithms and still is prone to errors in practice. comparatively widespread While text to-speech (TTS) and easy to implement, general speech recognition is a difficult problem especially in a quite unstructured scenario such as a dental office. By updating large amounts of data, neural networks have proven to be a promising approach [5].

### Artificial intelligence-robotic bonding

John McCarthy in the year 1956 coined the concept of artificial intelligence (AI). Repeated analysis for the model has led to the development of AI. AI defined it is a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior and with creation of artifacts that exhibit such kind of behavior [6]. Artificial intelligence in the contemporary of robotic technology, with the scientific informations of autonomous task planning containing methods from classical artificial intelligence such as tree-search algorithms and symbolic task planning that are used to autonomously plan a sequence of actions in order to achieve a desired goal. Most of these methods taken from works that are unrelated to robotics yet very much applicable. An insight of heuristic planners can be found in an incremental version of the well-known algorithm (which is used in various contexts to search for optimal solutions, e.g. path planning, action planning or scheduling) is developed [7]. Generally, autonomous robots depend on a knowledge base in order to reliably perform their assigned tasks. Examples for stored knowledge are taxonomies of skills, i.e. the capabilities of the robot, 3D-maps of the surroundings or general information about the robot. Furthermore, they have to be able to reason about current events and new information in order to adapt to new situation [8].

### Artificial intelligence and their working capability

AI may be concerned as a subject which deals with computerized models that can think and act or perform tasks rationally. Artificial neural networks (ANNs) are inspired by human neural system or biological nervous system, which are highly interconnected networks of computer processors systems [9]. ANNs simulate the neural signal transmission and the human brains serves as an essential part of AI [10]. Programming languages are the principal tools of AI in understanding these symbolic information systems. Development of ANNs is based on the human brain structure or biological brain structure and they can recognize pattern such as human brain, manage data, and learning. The most important advantage of ANNs is that this system solves problems which are too complex to conventional techniques and also, those that do not have an algorithmic solution can be solved with the help of ANN. They are utilized in various fields of medicine like, for diagnosis or diagnostic systems, biomedical analogies, development of drugs, and image analysis [11]. Strong AI means a system that works in the same way as human intelligence through unnatural, software construction, and artificial hardware. It is a theoretical form of machine intelligence [12]. The key feature of strong AI involves reasoning ability, puzzlesolving, judgment making, planning, learning, and communicating, i.e., the capacity of machines to perform human tasks and replicate or reproduce human behavior efficiently [13].

### Machine learning in AI based robots

It is one of the sections in AI that provides knowledge to computer systems through data and observations without actually being programmed. This allows a computer to correctly generalize a setting by tuning or adjusting the parameters within the algorithm to achieve the fitness between the input (i.e. text, image, or video data fed into the algorithm) and output (i.e. classification) [14]. For example, for a machine learning (ML) algorithm can recognize or detect a lymph node in the headandneck image as normal or abnormal provided it is trained radiologist by analyzing thousands of such images which are labeled as normal or abnormal [15]. To sum it up ML algorithms are trained to provide a correct specific answer by examining or learning a huge number of procedural tests that have been handlabeled. Representation learning Is a subtype of ML in which the computer algorithm systems studies about the features necessary to categorize the data that are provided [16]. This does not require a hand labeled data like ML. Deep learning Is a subgroup of representation learning relying on multiple processing layers (hence, deep) to seek knowledge about representations of data with one or more multiple layers of abstraction [17]. This algorithm uses multiple layers to detect simple features such as line, edge and texture to complex shapes, lesions, or whole organs in a hierarchical structure [18]. Basis of any radiologic interpretation is the logical elimination of possible diagnosis [19]. Hence, deep learning can be exceptionally good by learning a specific type of hierarchical normal representation of particular image from a huge number of normal examinations.

## Artificial intelligence-based robots in different fields of dentistry

### Artificial intelligence-based robots in patient management

Virtual dental assistants which are based on AI can perform various functions and tasks with greater accuracy in the dental clinic, minimal errors, and less workforce compared to humans [20]. In the departments such as oral medicine and radiology, oral pathology, it can be used to arrange appointments, managing insurance and article works as well as helping in diagnosis or planning treatment. It is very helpful in notifying the dentist regarding patients' complete medical and dental history as well as other oral hygiene habits, food and diet habits and habits such as alcoholism and smoking [21]. In dental emergencies, the patient has an option of emergency teleassistance, especially when the practitioner is unavailable [21]. Thus, a comprehensive virtual data of the patients can be generated which will help in providing ideal treatment for the patient in long run [22].

### Artificial intelligence-based robots in diagnosis and treatment

For a successful clinical practice, correct diagnosis is a strong foundation. In this concern, efficiently trained neural networks can be a precious present to diagnosticians, particularly in the diseases and conditions with multifactorial cause or etiology [23]. To say, recurrent aphthous ulceration is one of the conditions without a specific etiology or with multiple etiology, where the clinical diagnosis is given based only on the recurrence of the lesion and excluding the other factors [24]. In this regard, AI can be considered as one of the useful and ideal modalities in diagnosing and treatment planning or treating of oral mucosal lesions and can be utilized in examining and grouping doubtful or unsure altered mucosa which is considered to show premalignant and malignant changes [25]. Even minimal to minute changes at the level of single pixel which might go undetectable by the human eye can be detected. AI can precisely prognosticate the predisposition of genes in oral cancer for a large population [26].

### Artificial intelligence-based robots in oral and maxillofacial surgery

The huge application of AI in this field is the development of robotic surgery where the stimulation of human body motion and human intelligence is shown by AI [27]. Successful clinical application in imageguided surgery in the cranial area includes oral implant surgery, removal of tumor and foreign bodies, biopsy, and temporomandibular joint surgery [27]. The development of computer-assisted implant surgery based on the concept of prosthetic-driven implantology and CT-scan analysis have been reviewed. Few comparative studies in the literature of using AI in oral implant surgery indicate significantly more accuracy compared to manual freehand procedures even if performed by experienced surgeons. In addition, no significant difference between experienced surgeon and trainees were identified [27]. In spite of that shorter operation time, safer manipulation around delicate structures and higher intraoperative accuracy has been recognized with the help of AI. Image guidance allows thorough surgical resection which may decrease the requirement of revision procedures [27]. A pilot phantom study concluded that implant placement with a six-axis robotic arm can improve accuracy of the operation in zygomatic implant placement [28]. The authors recommended to implement force feedback by adding a haptic device to the presented system in future research. A surgical robotic application which has made it to reality is an invasive robotic assistant for dental implantology. It was permitted for operative use by the FDA (Food and Drug Administration) in March 2017 [28]. The product is called Yomi and is produced by Neocis (Neocis Inc., Miami, USA). Based on 3Ddata from a CT the dentist plans the implant position [28]. During surgery the robotic arm drills the hole in the jawbone and places the implant according to the planning while the dentist can follow the position of the burr in real-time, owing to the software, which allows the dentist to adjust placement position of the implant intraoperatively [28].

### Artificial intelligence-based robots in prosthetic dentistry

In order to render ideal flawless esthetic prosthesis for the patient various factors such as facial measurements, anthropological calculations, ethnicity, and patient preferences has been integrated by a design assistant which uses AI (RaPid) for use in prosthodontics [29]. RaPiD integrates computeraided design (CAD), knowledgebased systems and databases, recruit a logicbased information as a unifying medium Preparation of a tooth for crowns and bridges is a routine task for the dentist, although even after years of practical experience it is still challenging [29]. The challenge is to reduce the tooth sufficiently to create space for the prosthetic rehabilitation with a minimum of damage to sound tooth structure. The idea of a robotic arm used for tooth preparation or preparation support for the dentist seems tempting and sensible [29]. A mechatronic system to support the dentist in drilling has been tested *in vitro* and showed good results, however, it has not yet been validated in a clinical setting [29]. The dentist's position accuracy was 53% better with the mechatronic system than without it. Yuan., *et al.* [29]. described a robotic tooth preparation system with the following hardware components: (1) an intraoral 3D scanner (TRIOS, 3Shape A/S, Copenhagen, Denmark) to obtain the 3D data of the patient's target tooth, adjacent teeth, opposing teeth and the teeth fixture; (2) a computer-aided design (CAD)/computer-aided manufacturing (CAM) software for designing the target preparation shape and generating a 3D motion path of the laser; (3) an effective low-heat laser suitable for hard tissue preparation; (4) a 6 DoF robot arm; (5) a tooth fixture connecting the robotic device with the target tooth and protecting the adjacent teeth from laser cut ting, designed using Solidworks software (Dassault Systèmes SOLIDWORKS Corporation, Waltham, MA, USA) [29].

### Artificial intelligence-based robots in orthodontics

Diagnosis and treatment planning can be done in orthodontics by the analysis of radiographs and photographs by intraoral scanners and cameras which works on the principles of AI [29]. This eliminates the requirement for making patient impressions as well as several laboratory steps that are usually followed. From this, the results are usually much more accurate compared to human perception. The tooth movement and final treatment outcome can be predicted by using algorithms and statistical analysis [29]. Applications of artificial intelligence. A novel system that generates the dental arch form has been developed [29]. The system can be used to bend orthodontic wires. Edinger described a robot for the dental office for the first time in 1991, later he described a robotic system to reproduce condylar movements [29]. Virtual articulators are one of the technological bases necessary to fully rethink and digitalize dental workflows [30]. They enable simulation of occlusal changes in the digital world and may be strongly empowered by AI in the future to e.g. simulate use of dental materials patient-individually or simulate treatment outcomes of implant placement or maxilla-facial surgeries.

### AI based robots in maxillofacial radiology

X-ray imaging radiography. Positioning of the film/sensor and the X-ray source was proposed to be executed by a 6 DoF robotic arm and was found to have no adverse effects. Results showed that the robotic system was superior to the mechanical alignment approach, due to its excellent accuracy and repeatability [30]. Another application presented in the literature is a robot equipped with a skull to investigate the influence of head movement to the accuracy of 3D imaging its clinical applications can be divided into three types 1. Clinical workflow 2. Types of applications 3. Classes of use cases [30].

### AI based robots in endodontics

Root canal treatment is a procedure which is based on high accuracy. Usually, a dentist specialized in endodontics works using magnification to assure adequate view of the root canal. Nelson., *et al.* published the idea of a robotic system for assistance during root canal treatment. The so-called "vending machine" was supposed to supply the dentist with the necessary root canal instruments during treatment in order to reduce deflection from the operating site [31]. A recent study proposed the application of micro-robots with catalytic-ability to destroy biofilms within the root canal and tested the system *In vitro* [31].

### Robots in dental education at universities

In 1969 described a dental training robot. The humanoid application in dental education was tested in 2017 a full-body patient simulation system (SIMROID) A humanoid, among dental students to find out whether a robotic patient was more realistic for the students to familiarize with real patients was tested in a study than the usually used dummies [32]. "Hanako", the SIMROID is standing 165 cm tall [32]. It is made of a metal skeleton and vinyl chloride-based gum pattern of skin. "Hanako" an interesting contribution to education in dentistry as the SIMROID is imitating a human in its actions and expressions. It can verbally express pain, roll its eyes, blink, shake its head in pain, perform movements of jaw, tongue, elbow and wrist [33]. Furthermore, it can even simulate a vomiting reflex with a uvula sensor, and also simulate functions to induce bleeding and saliva flow. Tanzawa., *et al*. Introduced a medical emergency robot with the aim to help dental students to get familiar with emergency situations [33]. Another robotic educational equipment described in the literature is the ROBOTUTOR. This tool was developed as an alternative to a clinician to demonstrate tooth-cleaning techniques to patients. It is a robotic device to train and show brushing techniques [33]. A study among patients showed that the ROBOTUTOR was the most attractive method (according to patient evaluation) for dental health care education compared to other methods (clinician or video audio tutorial) [33]. However, it was less effective than the clinician. A haptic-based tooth drilling simulator was introduced for dental education with an implemented collision detection system to give force sensation to the user and make the virtual reality (VR) experience more realistic [34]. A study found best learning of dental basic motor skills in trainees receiving a combination of VR training with haptic feedback and human instructor verbal feedback [34]. Other studies investigated the use of VR and haptic devices for training of dental implant placement or oral anesthesia. haptic devices with VR laboratories become more and more part of the regular curricula in dental education and have been found to improve student's learning efficiency and effect [34].

## Conclusion

Robotics in dentistry is still emerging. but, research over this field is still scanty. Only some studies proposed robotics Throughout the literature authors claim that robotic systems enhance reliability, reproducibility and accuracy in their test applications. Despite this, the amount of research done in this field is still limited due to lack of available and accessible systems in recent years. Artificial intelligence of machine learning and understanding the various concepts along with the haptics in robotic technology involved will have a clear advantage in upcoming days, which has more scope for the cognition multitasking technology [35]. The research should be integrated with dental clinical procedures for better results. Even though advanced sign natural language processing, image recognition, neural networking and speech recognition are on the anvil the high initial costs can often be a slow process. AI based robots can certainly be tool in making significant progress in delivering better healthcare to the patient, but in no way can replace human knowledge, skills, and power of judgment. Another reason why robotics is still a field of low interest in dentistry may be the lack of expert knowledge to program and control those systems as a non-professional. most interdisciplinary research combining engineering and dentistry in the field of Dentbots focuses on implantology, although the invasive character of this application may impair acceptance of this technology among patients and dentists. For clinical scientist the idea of having a swarm of micro-robots to destroy biofilms is tempting, considering the impact of biofilms in oral diseases such as caries, periodontitis, mucositis or peri-implantitis [35]. Hence, these most invasive applications are little suitable as forerunners. Therefore, research in the field of assistive robotics seems to be more promising to facilitate the introduction of this new robotic enabled era.

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