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Review Article

Artificial intelligence in robo dentistry: A double-edged sword

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ABSTRACT

As technology continues to advance at an unmatched pace, artificial intelligence (AI) has become an omnipresent presence in our lives. Artificial intelligence (AI) is a technology that utilizes machines to imitate intelligent human conduct that is because of its intense capabilities in data analysis, and virtual algorithms. These capabilities can increase the efficacy of AI robots in dental diagnosis, and treatment plans and also to assess the prognosis of various oral diseases. Apart from benefits, there are several unwanted consequences while doing the AI-assisted operation, the dentist is still required to monitor the whole process. In various case scenarios like data error, any circuit interruption, or some other unexpected conditions, if something happened, the consequences would be unimaginable. Robodentistry is like a coin having two faces. One face helps patients in a better way like a dentist but the other face when turned up, can pose big problems. So, still, more researches are required before thinking that robots can do the job autonomously in dentistry.

1. Introduction

John McCarthy originally introduced this field of applied computer science known as artificial intelligence in 1956. It is, at times, called machine intelligence.[1] AI is a next-generation technology that has already aided the medical field in achieving new frontiers. AI has given lives to machines that are now more capable than a surgeon to operate on a living being. Robots in dentistry can do various tasks that generally require high cognitive skills such as interacting with patients.[2] Other than that, they can work as dental assistants, which is one of the big debates for robotic dentistry.[3] By doing hours of long procedures in clinics, Dentists encounter weariness, which can lead to mistakes while doing oral examination, or while making appropriate diagnosis and treatment plan. However, incorporating AI robotics in dentistry can help minimize errors. Robots in concert with 3D navigation can be used for invasive dental procedures, like tooth preparation and autonomous dental implant placement.[4,5] Moreover, robots can play a role in dental education too. However, research data on the therapeutic reliability and precision of autonomous robots is very limited. In this article, I will discuss the various applications of AI robots in the various fields of dentistry and will also discuss its effects on health care.

2. What Is AI-Powered Robots?

AI-powered robots are built up with a variety of sensors which include vision devices such as 2D/3D cameras, vibration sensors, proximity sensors, accelerometers, and other environmental sensors that load them with sensing data which they can analyze and act upon in real-time.

To better understand what AI-enabled robots are, it's important to understand what makes them intelligent.

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Artificial intelligence refers to a class of systems that enable machines to imitate advanced human capabilities. There are many ways to achieve AI, as shown in Figure 1.[2]

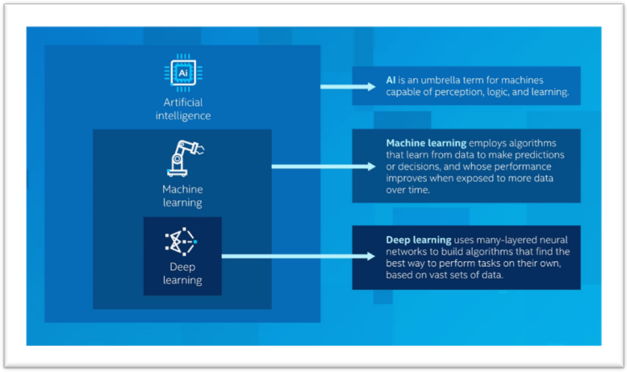

Figure 1: Ways to Artificial intelligence[2]

3. Its Application in Dentistry

3.1. In Operative Dentistry

Generally, dentists diagnose caries by visual method, tactile method, and radiography. Other than that, caries-detecting dyes, fiberoptic transillumination method, and electronic caries monitors have been widely used and regarded as highly reliable diagnostic tools for detecting dental caries.

3.1.1. Detection of dental caries

In operative dentistry, various research has been done on the detection of dental caries, vertical root fractures, apical lesions, pulp space volumetric assessment, and evaluation of tooth wear.[6–11] In a two-dimensional (2D) radiograph, each pixel of the grayscale image has an intensity, i.e., brightness, which represents the density of the object. From these characteristics, an AI algorithm can learn the pattern and can give predictions. In a study done by Lee et al. on the Detection and diagnosis of dental caries by using a deep learning-based convolutional neural network algorithm, and concluded that A deep CNN algorithm provided considerably good performance in detecting dental caries in periapical radiographs.[12] Similarly, Another study by Kuhnisch et al. also proposed a CNN algorithm to detect caries on intraoral images.[13]

3.1.2. Nanorobots

Nanotechnology-based dental nanorobots can be utilized for tooth repair, local drug delivery, dentin hypersensitivity, single-visit orthodontic realignment, endodontic and conservative dentistry, cavity preparation and restoration, local anesthetic, and dental robotics. The nanoscopic dental robots offer quick and accurate care.[14]

3.2. Endodontics

3.2.1. Various applications in endodontics

The AI models can do different jobs in endodontics, includes to study the anatomy of the root canal system, speculating the viability of stem cells of the dental pulp, estimating the working length of a tooth, detecting root fractures and periapical lesions, and also in forecasting the success of retreatment procedures. Nelson and colleagues suggested the concept of a tool vending machine or a robot system that assists the dentist while performing root canal therapy.[15]

3.2.2. Endo micro robots

They were created to enhance endodontic treatment's precision and effectiveness and provide top-notch root canal therapy. The endo micro robot accomplishes autonomous drilling, cleaning, shape, and three-dimensional filling of the root canal system with the aid of cutting-edge computer-assisted endodontic technology through online supervision and an intelligent system. It gives precise treatment with error-free outcomes, causing the dentist less discomfort and anxiety. Micro position and orientation adjustment equipment, a travel distance controller, microsensors, an automatic feed rate, and apex sensors with flexible drill and vacuum attachments are all components of an endo-micro robot.[16]

3.3. Oral and Maxillofacial Surgery

3.3.1. Detection and diagnosis of oral cancer

Surgery resection is required mostly for malignant lesions. To avoid surgery, early diagnosis and detection of mucosal lesions is essential. In some cases where lesions behave similarly in appearance, they require a definitive diagnosis by biopsy or by radiographs. In a study by Abureville et al. where they used a CNN (Convolutional Neural Networks) algorithm, to diagnose oral squamous cell carcinoma (OSCC) from confocal laser endomicroscopy images (7894) in patients diagnosed with OSCC and the results showed that the CNN algorithm used in the study was good for early diagnosis of SCC.[17] Another similar study by Poedjiastoeti et al. in which they have also used a CNN algorithm to identify and distinguish ameloblastoma and keratocystic odontogenic tumor (KCOT) and the results are positive.[18]

3.3.2. Surgical and implantology robots

Application of robotics in oral and maxillofacial surgery, where the surgeon programs the robot at the time of surgery after which the robot performs pre-programmed tasks in the operation theatre such as osteotomy cuts, milling, and drilling of bones, by selecting and positioning of plates and while doing surgical planning, etc.[19–21] Computer-assisted surgery for guided implant placement is accomplished by getting a 3-D model that resembles the patient's jaw formed

from the cone-beam CT imaging data. The robot is then commanded to drill a jaw splint at the site planned by the software planning system which acts as a surgical guide.[16]

3.3.3. Robotic dental drill

In this, a very fine needle is used to pierce the gum to find a site of the alveolar bone in a patient with a restrained jaw.[16]

3.4. Periodontics

3.4.1. In the diagnosis of periodontal diseases

AI has been utilized to diagnose periodontitis and classify numerous periodontal disease types.[22,23] In addition, Krois et al.,[24] Lee et al.,[25] and Yauney et al.[26] adopted the CNN algorithm in the detection of periodontal diseases like periodontal bone loss (PBL), detection of periodontally compromised teeth, etc.

3.4.2. Tooth cleaning robots

Several in vitro results revealed the capability of the robotic system to exhibit reproducible significant differences in the cleaning efficacies of powered toothbrushes.[27,28]

3.5. Prosthodontics

3.5.1. Tooth-crown preparation robots

LaserBot, a microrobot is a robotic device that achieves the precise three-dimensional (3D) motion control of a femtosecond laser beam in tooth-crown preparation.[29] Some of the researchers conducted experiments on wax, resin, and teeth by using a system that combines robotic and laser technology to achieve automatic 3D tooth ablation and the results proved that the robotic system could meet the requirements for dental crown preparation.[30]

3.5.2. Tooth–arrangement robots

Zhang et al. proposed the concept of a professional and miniature Cartesian coordinate-type tooth-arrangement robot to solve the time-consuming and low-precision problems of traditional tooth-arrangement methods.[31]

3.5.3. Robotic articulator

It uses a precise six-axis micro-positioning stage to reproduce the patient's functional mandibular movement with six Degrees of freedom. Using this type of articulator system, a full veneer crown restoration is made up without the need for intraoral occlusal adjustments. However, further research is needed to evaluate this technique.[32]

3.6. Orthodontics

3.6.1. Orthodontic arch wire bending robots

This robotic technology is also used for bending orthodontic archwires. SureSmileArchWire bending robot is known for bending archwires. Similarly, "LAMDA (Lingual Archwire Manufacturing and Design Aid)" contains a heater that can raise the temperature of a nickel-titanium archwire to 600 °F and bend it within 6 min. Gilbert did a study in which, he did the blind evaluation of the archwires which were manually bent by 15 lingual orthodontic specialists, and the archwires bent by the LAMDA system. The results showed that the LAMDA system had a higher score than the archwire bent by 15 lingual orthodontic specialists.[33]

3.7. Others

3.7.1. Masticatory robots

Masticatory robots are robots, that can simulate human chewing motion. It can be used for the recording of jaw movement in patients, who require prosthetic rehabilitation. It can also be used for research purposes in the diagnosis of temporomandibular joint diseases or the study of mandibular kinematics during speech.

3.7.2. Dental patient robots

For clinical training of dentists and dental students, dental patient robots are designed. They are called "Phantoms". The most used dental patient robots are Geminoid DK, Showa Hanako, and Simroid.

4. Adoption Challenges to AI Robots

4.1. Potential risk for the patient

Apart from benefits, there are several unwanted consequences while doing the AI-assisted operation, the dentist is required during the whole process. Data error, circuit interruption, or inadequate data storage in AI robots can hamper the treatment of patients. On the other hand, some complex procedures like in some implant patients who need bone grafts, and in case of retrieval of a broken file from the tooth while doing a root canal are difficult to finish by robots alone. In these cases, the efficiency of dentists as compared with dental robots is still indispensable. A dentist can make a mistake on one patient however, an improperly functioning AI robot can cause harm to many patients.

4.2. Lack of research data and guidelines

Various studies have been published so far on AI robots, but due to lack of standardization, and guidelines on machine learning studies, they are not much significant. So, it is recommended to make guidelines and reporting standards for machine learning studies related to dentistry. There is also a need for clinical trials with approval from regulatory bodies for implementation in clinical contexts. AI robots are in the stage of theoretical research and under the preliminary experimental stage which requires professionally trained and experienced operators and because of this they are not widely used in clinical practice.[34]

4.3. Trust issues

The trust relationship between patients and medical professionals always should be on good terms, but adding AI into the picture will likely impact the trust of the patient first. We all know AI robotics are performing well in these initial stages of experiment but, doctor surveillance is still important. AI Robots operate logically, but healthcare professionals do not. If doctors become intelligent users of AI robots, they may hold the trust relationship between patients and doctors but many patients, who have a limited understanding of modern-day technologies, may face great difficulty in trusting AI robots.[35] Robots are machines, not humans. From a patient's point of view putting all hopes and belief in a machine that it will work more precisely and better than a doctor is wrong. Even our society thinks the same. In another field of robots, some incidents have happened in the past where the rise of safety concerns of humans arose on a large scale.

4.4. High cost

Mechanical improvements in clinical/dental applications are very costly for the doctor and the patient too. Most common and repetitive procedures like scaling, curettage, restoration, and bonding of orthodontic wires in the oral cavity lack the application of robotic technology. For repetitive and smaller tasks using robots becomes very costly for the patient.

4.5. Security or privacy issues and the ethical dilemmas

The priority for a doctor is always the patients' safety. In a situation where AI robot storage data is insufficient, inaccurate, or affected due to cyber-attacks, the risk of error increases in the judgment and execution by the robots. The issue of privacy looms in the application of AI technologies and can have negative consequences for patients, dentists, and the associated institutions.[36]

Furthermore, the ethical dilemmas posed by the use of robots to replace humans in diagnosis and treatment is another issue of debate.

4.6. Unemployment in the dental sector

Using robots in dentistry somehow leads to unemployment just like robots did in the industrial sector. The number of staff working for a doctor will reduce leading to displacement in the job.

4.7. Responsibility, accountability, and liability

Who is responsible for AI robot-generated mistakes? Is it the programmer, manufacturer, user, or the AI/robotic system itself? The answer is uncertain. The European Parliament's 2017 Resolution on AI assigns legal responsibility for an action of an AI or robotic system to a human actor, which may be its owner, developer, manufacturer, or operator.[37]

4.8. Inappropriate data quality

According to various research, the reliability and quality of data which is received from various sensors and digital healthcare devices are not very clear. The Datasets in medicine are still imperfect and that was happening due to documentation error or incomplete data error. So, it is very difficult to develop an error-free machine learning AI robotic model.[38]

5. Conclusion

Robodentistry has both positive and negative effects on dentistry. On one side it can provide better patient outcomes by assisting dentists in oral examination, diagnosis, and treatment planning, and also by doing small procedures on patients that can help to minimize errors and enhance the overall quality and quantity of patient care. On the other side, there are several health, safety, and privacy concerns arise that somehow restrict their use in dentistry autonomously. However, to date, evidence of AI robots' performance in the context of big data in dentistry is lacking. More studies are still required to further verify the reliability, applicability, and cost-effectiveness of AI robots before transferring these robotic models into the day-to-day clinical practice.

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None.

7. Conflict of Interest

None.

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