REVIEW ARTICLE

Artificial intelligence: the real buzz in dentistry

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Abstract

Artificial intelligence (AI) is evolving into a driving force that defines the course of the world. It has significant impact on dentistry as a whole, where it helps in the diagnosis, treatment planning and prognosis evaluation in several clinical scenarios. The various models of neural networks help in the refinement of the technology available.AI is indeed a growing phenomenon that is unavoidable and is the gateway to an unimaginable future. The various limitations and concerns regarding AI is to be monitored and researched upon for the sustainability of the technology involved.

Keywords: Artificial Intelligence, AI, Future, Dentistry, Robotics, Technology

Introduction

Artificial intelligence (AI) can be defined as the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as recognizing speech, making decisions, and identifying patterns.

[1] AI is an umbrella term that encompasses a range of technologies, including machine learning, deep learning, and natural language processing (NLP). In dentistry, AI has been adopted in all dental disciplines and most of the AI applications in dentistry go to the diagnosis based on radiographic or optical images, while other tasks are not as applicable as image-based tasks mainly due to the constraints of data availability, data uniformity, and computational power for handling 3D data.[2] As the scope of AI is setting a considerable mark in all the branches of dentistry, this article emphasises largely on the applications of AI in the field of operative dentistry and endodontics.

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History of AI

The major developments have been occurring in the field of AI since 1950 and are:

1950- Alan Turing published "Computing Machinery and Intelligence", which proposes the Turing test as a measure of machine intelligence and answered all of the most common objections to the proposal "machines can think".

1951- The first working AI programs were written in 1951 to run on the Ferranti Mark 1 machine of the University of Manchester.

1956- The term 'Artificial Intelligence (AI) was coined at the Dartmouth summer AI conference. The first AI program – 'Logic Theorist' was created by Allen Newell, J.C. Shaw and Herbert A. Simon.

1958-John McCarthy (Massachusetts Institute of Technology or MIT) invented the Lisp programming language.

1960- Ray Solomonoff lays the foundations of a mathematical theory of AI, introducing universal Bayesian methods for inductive inference and prediction. "Man-Computer Symbiosis" by J.C.R. Licklider.

1963- Edward Feigenbaum and Julian Feldman published Computers and Thought, the first collection of articles about artificial intelligence.

1974- Ted Shortliffe's PhD dissertation on the MYCIN program (Stanford) demonstrated a very practical rule-based approach to medical diagnoses, strongly influenced the future of expert system development, especially commercial systems.

1978- Herbert A. Simon wins the Nobel Prize in Economics for his theory of bounded rationality, one of the cornerstones of AI known as "satisficing".

1980- First National Conference of the American Association for Artificial Intelligence (AAAI) held at Stanford.

1997- The Deep Blue chess machine (IBM) defeats the (then) world chess champion, Garry Kasparov.

2009- Google builds autonomous car.

2010- Microsoft launches Kinect for Xbox 360, the award winning and first gaming device to track human body movement, using just a 3D camera and infra-red detection.

2011-14- Apple's Siri (2011), Google's Google Now (2012) and Microsoft's Cortana (2014) are smartphone apps that use natural language to answer questions, make recommendations and perform actions.

2012- AlexNet, a deep learning model developed by Alex Krizhevsky, becomes a turning point in the history of AI.

2020- Microsoft introduces its Turing Natural Language Generation (T-NLG), which is the "largest language model ever published at 17 billion parameters."

2022- ChatGPT, an AI chatbot developed by OpenAI is released. It is initially built on top of the GPT-3.5 large language model. By January 2023, ChatGPT has more than 100 million users, making it the fastest growing consumer application to date.

2023- Google's Bard transitions from LaMDA to PaLM2, a significantly more advanced language model.

It is to be noted that constant and rapid developments occur in the field of AI.

Classification of AI

They are classified as Type 1 and Type 2.

Type 1 is based on capability of AI and is categorized into 3:

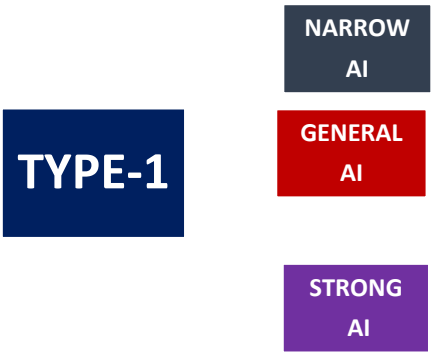

Fig.1

1. **Narrow AI** - This AI is able to perform a dedicated task with intelligence. It is the most common and currently available AI. It cannot perform beyond its field or limitations, as it is only trained for one specific task and is also termed as weak AI. Examples are playing chess, purchasing suggestions on e-commerce site, self-driving cars, speech recognition, and image recognition.

2. **General AI** - It is a type of intelligence which could perform any intellectual task with efficiency like a human. The idea behind the general AI to make such a system which could be smarter and think like a human by its own. Currently, there is no such system exist which could come under general AI and can perform any task as perfect as a human.

3. **Super AI** - Super AI is a level of Intelligence of Systems at which machines could surpass human intelligence, and can perform any task better than human with cognitive properties. It is an outcome of general AI. Some key characteristics include capability include the ability to think, to reason, solve the puzzle, make judgments, plan, learn, and communicate by its own. It is still a hypothetical concept of Artificial Intelligence. Development of such systems in real is still world changing task.

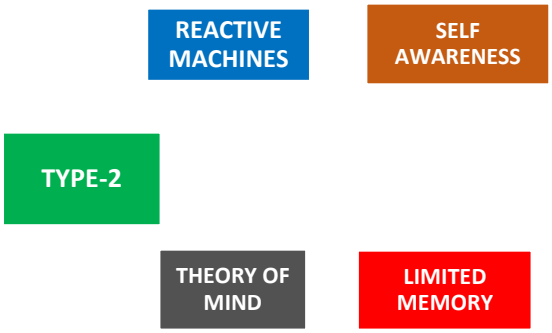

Fig.2

Type-2 is based on the functioning of AI and is categorized into

1. **Reactive Machines:** Purely reactive machines are the most basic types of Artificial Intelligence. They do not store memories or past experiences for future actions. These machines only focus on current scenarios and react on it as per possible best action. Examples; IBM's Deep Blue system, Google's AlphaGo.
2. **Limited Memory:** Limited memory machines can store past experiences or some data for a short period of time. These machines can use

stored data for a limited time period only. Examples: Self-driving cars,Apple's Siri.

3. **Theory of Mind:** It says AI should understand the human emotions, people, beliefs, and be able to interact socially like humans. They are still not developed, but researchers are making lots of efforts and improvement for developing such AI machines.
4. **Self-Awareness:** It is the future of Artificial Intelligence. These machines will be super intelligent, and will have their own consciousness, sentiments, and self-awareness and will be smarter than human mind. It does not exist in reality still and it is a hypothetical concept.

Application Branching of AI

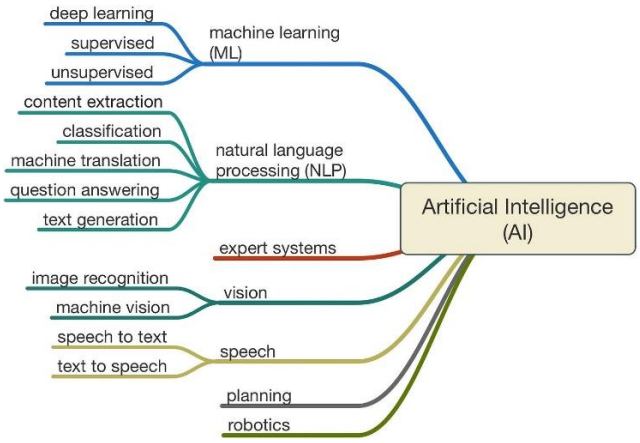

Fig. 3 (Source:https://intelligent-information.blog/de/macht-ki-unsere-informationen-intelligent/)

Artificial Intelligence System

The function of AI is principally by machine order of Input, Processing, and Output. AI in dentistry involves input data including text, image and voice data which are processed by the neural networks to provide an output.

The result might be a prognosis, diagnosis, treatment, or disease prediction. It can interpret clinical cues, do cephalometric analysis, or recognize lesions based on voxel differences to arrive at a diagnosis. It predicts the treatment of the provided input by distinguishing the normal structures, stimulating and evaluating the outcomes, converting the voice data, or bridging data acquisition and CAD/CAM. The artificial intelligence program may anticipate the disease or its prognosis by gene analysis, risk factor prioritization, or outcome prediction.[3]

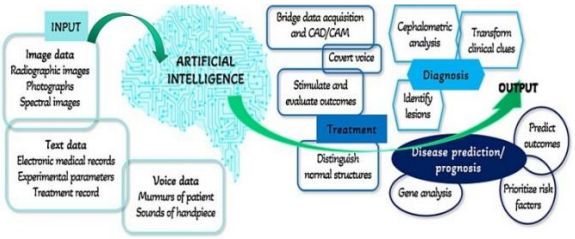

Fig.4 Hierarchy of Artificial Intelligence System[3]

Applications of artificial intelligence in Operative dentistry and Endodontics

In the speciality of operative dentistry and endodontics, AI is gaining more relevance. Its significance in treatment planning and disease diagnosis is valuable. The various applications include:

1. Detection and treatment of Dental Caries

Various types of caries and its progress in a tooth can be analysed using computer vision systems, using techniques like object detection and semantic segmentation. It is done by training Convolutional Neural Networks (CNN) on large sets of images with labelled carious lesions. Once the model training is complete, the algorithms are ready to be fed raw data to identify those lesions on their own. Deep learning (DL) models are also employed in caries diagnosis by analysis of radiographic and photographic images.

2. Tooth Restorations and Preparation

Tooth restoration design is done by model reconstruction. Use of Artificial intelligence based CAD (Computer Aided Design) software are employed along with analysis of data collected. AI models can be used to design restorations along with customisation of models. Intraoral scanners combined with AI analysis form an important tool in clinical diagnosis and treatment planning with precision.

3. Periapical Lesions detection

Periapical lesion management forms the basis for the prognosis of tooth affected. Various studies have been done using AI models for the same. A study by Orhan et al.[4] aimed to verify the accuracy of the Deep Learning (DL) system in the detection of a periapical pathosis by an AI system by segmentation of images, followed by volumetric measurement of the pathosis on CBCT images by both manual and AI systems. The authors concluded that AI systems were comparable to the manual segmentation methods and were 92.8% reliable in correctly detecting a periapical lesion.

Another study reported the utility of a DL-based system based on a U-net architecture to detect periapical pathosis. It employed a segmentation method that labelled the

voxel of CBCT into five categories such as "lesion" (periapical lesion), "tooth structure," "bone," "restorative materials," and "background.", following which repeated splits of the images were entered into the DL system to perform cross-validation. The detection accuracy of the DL-based algorithm was found to be 93% with a cumulative DICE index (similarity between two data sets, in this case, the manual method and the DL-based method) of 67% for the true positive lesions.[5,6]

4. Root Fractures Detection

CBCT along with other digital imaging are an important tool for Vertical Root Fractures (VRF), which is otherwise difficult to assess and helps in the treatment planning of the tooth concerned. The scan images can be used to form a neural network and then synthetically analysed to know the extent of involvement of fractures. The fracture extent or degree, site and surrounding structures can be mapped using neural network data sourced from imaging.

5. Access opening, Root Canal System and Morphology visualisation

The significance of the knowledge and assessment of the root system of a tooth is one of the primary basis of root canal therapy. Conventional radiographs and 3D imaging techniques are commonly used. Deep learning (DL) AI models have been proven to be highly effective in the visualisation and detection of root systems including segmentation and construction of augmented models for treatment planning proving almost absolute clarity of the dentition involved. It is particularly effective in roots with abnormal curvatures, decreases the chances of missed canals by the operator, perforation detection and repair and importantly, in calculating the positions of probable access openings of a tooth based on ML algorithms of AI models.

6. Determination of Working Length

The Working Length (WL) determination is one of the most essential part in root canal therapy. The accuracy of it has an impact on the treatment outcome. AI aided models help in more accurate determination of WL using Artificial Neural networks(ANN). Several studies including living and deceased samples have proven that employment of AI models offer greater precision compared to the traditional methods. It is used as a judgement model.

7. Retreatment Predictions

AI models are particularly helpful in Retreatment cases in the procedures and prognosis assessment. According to Campo et al.[8] for the prediction of the result of nonsurgical retreatment of the root canal with risks and benefits, a case-based reasoning paradigm was designed. In essence, the system advised on whether to retreat or not. The system contained information on statistical probability, performance, and recall. One of the system's strongest aspects is its ability to correctly forecast how the retreatment would turn out. The restriction was that the precision of the system could only match the information in the data. The process of coming up with solutions to issues based on experiences with related issues in the past important knowledge and information may be incorporated by obtaining related situations is case-based reasoning.[3]

8. Regenerative endodontics

Stem cell research has shown that regeneration of body tissues that are affected or missing is possible including teeth, bone, periodontium. Bindal et al. used the neuro-fuzzy inference method and assessed the stem cells extracted from the tooth pulp in many regenerative treatments. By assessing the stem cells survival following treatment with lipopolysaccharides of bacteria in a model clinical situation, this approach was able to predict the result.[3,9]

9. Assessment of Patient cases

AI can be used to diagnose patient cases using prediction, data collection and modelling. ANN models are used to predict the level of case difficulty using Machine Learning (ML) algorithm. This helps in the improvement of overall treatment planning and result, proving beneficial to the patient and operator.

Role of AI in other areas of Dentistry

- Orthodontics- Analysis of radiographs including cephalometric analysis, Tooth movement assessment, aligners, model construction and other treatment planning.
- Oral and maxillofacial surgery- Surgical planning and 3D image guided procedures, robotic surgeries, prosthesis design.
- Prosthodontics- CAD-CAM, Tooth margin design and preparation for crowns and bridges.
- Forensic odontology- Identification of age, gender and morphological analysis.
- Radiology- Used for interpretation and assessment of images with precision and accuracy, Oral cancer diagnosis and treatment.
- Patient education and awareness using simulation software and AI models.
- Management of Dental office and patients- Virtual assistance and feedback, scheduling of appointments, drug dosage calculations, maintaining of patient data records.
- Newer Researches- Tissue remodelling, reconstruction and Robotics.

Limitations of AI

Although the scope and benefits of AI is innumerable, there are few limitations and concerns regarding it which needs to be addressed constantly. They include:

- Highly vast amount of data is involved.
- Expensive- AI implementation requires investment in advanced infrastructure and training of operators.
- Less creative and innovative in challenging situations.
- Ethical and privacy concerns, constant monitoring is required.

The future of AI involves overcoming these and developing more technology for better functioning and output.

Conclusion

Artificial Intelligence (AI) has a major impact in the field of dentistry in the present and definitely has greater implications in the future. AI models using ML algorithms can help analyze patient data, identify pathologies and develop accurate treatment plans leading to a better prognosis. AI combined with the traditional methods including Evidence Based Dentistry (EBD) can offer higher clarity to the scope of treatment intended. Also, importance is to be given on increasing operator knowledge and skills, careful monitoring, overcoming limitations and prolonging advanced research.

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