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Review Article

Artificial Intelligence and its Application in Prosthodontics-A Narrative Review

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Abstract

Artificial intelligence (AI) was evolved nearly 70 years ago. It has involved many fields, primarily technology causing greater developments. Technological development was utilised in the advancement of many branches of health sciences, particularly Prosthodontics. This review narrates the early development of AI and the different products which were developed. AI improved the quality of prosthodontic treatment and precision. Implant dentistry and laboratory technology received high level progress within a short period of time. Scientists have raised a few ethical dilemmas which hopefully will be solved in the future. AI has a bright future in optimising prosthodontic treatment and dental education.

Keywords: Artificial Intelligence; Digital Dentistry; CAD/CAM; Digital Designing; AI Powered Artificial Organs

Introduction

A computer system which can perform tasks or functions, that usually requires human intelligence, like decision making, analysing the data, solving problems, speech recognition, visual perception, language comprehension, is designated in the present context as Artificial intelligence (AI) [1].

AI has found its effective use in medicine and dentistry, first in imaging diagnostics causing improvement in precision. AI can help in drug selection, monitoring the progress of hospitalised patients and the role has advanced to the use of robotics in clinical practice with a view to enhance quality of patient care. With the effective use of AI, dentists could reduce the work load physically, mentally and intellectually. Doing research was initially helped to find out the appropriate information sources through the internet. AI is capable of learning from multiple sources of information to diagnose disease conditions which is with almost unimaginable speed which human brain capabilities cannot match [2].

The beginnings of AI

The term or concept of artificial intelligence did not figure out till Alan Turing mentioned in his paper entitled Computing Machinery and Intelligence (1950) about 'thinking machines' which can be perceived as an equivalent to AI [3]. The machine's ability to think was evaluated by a test designed by Alan Turing in which questions were asked by an interrogator to a human being and to a computer through a text only channel. The answers were compared by the interrogator who could not see or hear and found out the resem-

blance between the human and machine answers. Correctness of the answers was not a consideration at all. If the human evaluator could not distinguish between the human being and the machine, it was considered as passing the Turing test and the machine was declared to have intelligence [4]. (Figure 1).

Figure 1: Alan Turing.

The term AI was formally proposed in a workshop conducted in 1955, led by John McCarthy et al., but its growth remained almost theoretical because of the storage limitations of the computers and the expensive nature of them. Related research was not supported by the authorities because the subject was quite new and faced conservative resistance [5]. By 1980, AI found two specific paths for the advancement like machine learning and expert systems. Machine learning allows the computers to learn by experience whereas the expert system simulates the decision making process of human experts. In 1997, an expert system – Deep Blue – played chess against Kasparov and defeated him. Late 2022 witnessed the arrival of ChatGPT (Chat Generative Pre-trained Transformer) which is a text generator [6-8]. Chat GPT can respond like humans in the text form if an input is given in a similar text form [9,10]. (Figure 2,3).

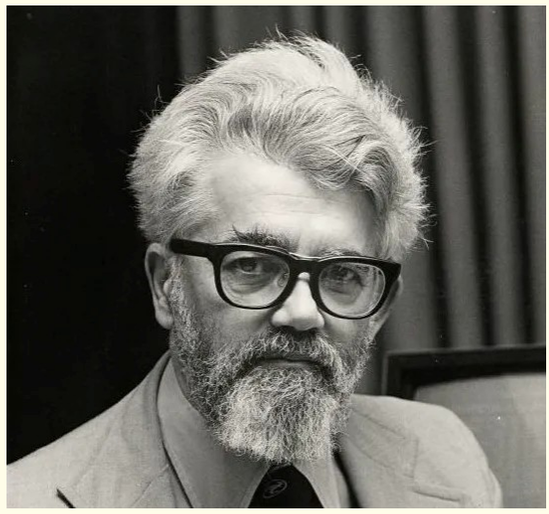

Figure 2: John-McCarthy.

Figure 3: Deep blue vs Kasparov (Carricature).

Machine learning and expert systems

Machine learning (ML) and expert systems were the next level of development. The former allows the computers to learn by themselves from experience whereas the latter needs human experts to provide inputs consisting of possible situations and solutions and from those, the expert systems will select appropriate solutions [11]. AI was tried in an expert system 'Deep Blue' which could play chess. In 1997, it could defeat the reigning chess champion Gary Kasparov. The score was 3.5-2.5. Researchers were inspired by this and created super computers which could solve complex problems.

Big data

Egyptians tried to store all the existing data in a library of Alexandria and it can be considered as the first attempt towards acquiring big data. Roman empire collected military statistics to have an idea on the army distribution. The large volume of informa-

tion generated was termed by scholars as information explosion (1941). In the US, large number of tax returns and finger prints were stored on magnetic tapes. The term big data was coined by NASA researchers when they felt the need of processing large quantity of data generated by supercomputers. In the health sector huge volumes of data generated from health records, imaging and patient feedback was processed by big data. In dentistry also it had relevance in integrating clinical data, treatment outcomes and demographics to make the practice and patient care more precise and personalised. The role of big data is summarised in the figure no…. Big data in fact refers to large, diverse collection of structured, unstructured and semi structured data that grows exponentially over a period of time. The huge data which is complex in volume, velocity and variety cannot be stored, processed and analysed with traditional management systems [12,13] (Figure 4).

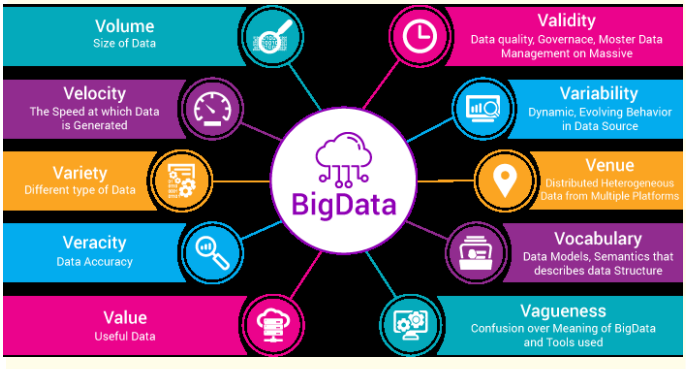

Figure 4: Big data characteristics.

Deep learning (DL)

Deep learning was evolved from machine learning which is an integral part of AI. Deep learning makes computers capable of learning from data and make decisions. DL can recognise complex data such as images, text and sound. DL is used in facial and speech recognition, fraud detection in credit cards, chatbots, medical image analysis, cancer detection and in the recently introduced self driving cars. DL enables in building knowledge from provided examples and perform like human beings because the algorithms are neural networks that are similar to those present in the human brain. In dentistry it has a wide variety of applications viz. disease detection, image analysis and handling of huge quantity of data [14].

ChatGPT

Chatbot is a computer program that can simulate human conversation in response to text or voice commands. Chatbot is an AI feature that can be used in many messaging applications, websites, social media platforms, and voice assistants.

ChatGPT is a chatbot that can create dialogues or conversations in response to questions. It can compose different written matters like essays, articles, posts for social media and even emails. OpenAI, a research company founded by a group of entrepreneurs and researchers, launched ChatGPT in November 2022. ChatGPT originally used GPT-3 large language model (neural network machine learning model) and the 3rd generation of Generative Pretrained Transformer. The transformer formulates the response from a huge quantity of data. Human trainers provide conversations and the responses are ranked. Users can provide feedback to improve the quality of responses.

Capabilities of AI

Capabilities of AI can be categorised as follows
Narrow (Weak) AI,
General (Strong) AI,
Superintelligent AI.

- Narrow AI is designed to perform a specific task. This is used in voice assistant system like Alexa and in online shopping. This AI system provides excellent service in a specified domain for which it is designed. It does not exhibit cognitive abilities of human intelligence.
- General AI has the ability to learn, understand and apply intelligence to perform different tasks comparable to a human being. Researchers are still working on it and at present it is living on the engineer's drawing board.
- Superintelligent AI is expected to supersede human intelligence and it remains as a concept and intellectuals are largely divided on its necessity. Though at present it has a fictional status, only future will tell whether it has a factual profile.

AI has brought in many useful applications in the language processing like Chatbots, language translation, speech recognition, text analysis and generation of responses. Another area is computer vi-

sion which can recognise objects and face, analysis of medical images and navigation of vehicles. AI provided an exciting frontier through robotics which are intelligent machines that are usefully employed in engineering, manufacturing, transport and as health care assistants. Expert system is a significant contribution of AI, used effectively in medical and dental diagnosis, provides advice in legal and financial predictions. The recent creative application, the Generative AI can produce meaningful responses in the form of text, images and audio [16].

AI in prosthodontics

The introduction of CAD/CAM to Prosthodontics has streamlined the design part of fixed prosthesis to be fabricated on a dentist prepared tooth. CEREC is a very popular system that combines digital scanning with a milling unit to fabricate fixed restorations in a single visit. AI algorithms can analyse intra oral scans, digital impressions and 3D models and can make prosthesis which has superior fit. AI can automate design tasks and can suggest changes in the design based on historical data and anatomic specifications. Additive manufacturing has provided another dimension to the fabrication of fixed prosthesis. Laser sintered crowns are made from base metals like cobalt-chromium alloys. In CAD, the crowns are designed from a library which the system has kept. Though attempts are made, custom made crown designs for individual patients are yet to be achieved successfully. AI helps in shade matching and can do prognostication of the restorations especially on debonding [17,18]. (Figure 5).

Figure 5: CAD-CAM milling machine.

Digital work flow is much streamlined now which encompasses initial intra oral scanning that can be sent to the CAD/CAM software. This software is capable of designing the prosthesis and later proceeding to the fabrication of the prosthesis either by milling or by printing as per the requirement. Different types of fixed prostheses are fabricated like crowns, fixed dental prosthesis and onlays. AI driven CAD/CAM is capable of identifying the preparation margins and label the margins. AI helps in reducing the possibility of incorporating human error and improving the accuracy [19-20]. AI can generate occlusal morphology corresponding to the morphology of the opposing teeth [21].

AI and dental implants

Precision and predictability in dental implant treatment were enhanced after the popular use of CBCT and intra oral digital scanning. AI helps in recognising the type of implant from radiographic images. AI can analyse osseointegration, bone architecture and finite element analytical calculations and predict the prognosis of the treatment. AI can evaluate the stress generated at the bone-implant interface in the context of the size and thread characteristics of the implant. AI determined success varies between 60-80% [22].

Recognising implant types from radiographs using AI seems to be highly refined and the precision obtained is in the range of 93-98%. AI can help in the fabrication of implant prosthesis, tooth selection, marginal fit and reduction of errors with implant prosthesis interface. Refinement in design and development of new generation of implants is going to be definitely dictated by AI [23]. (Figure 6).

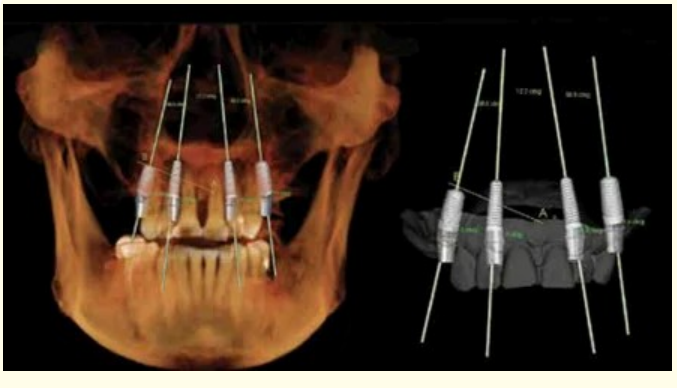

Figure 6: CBCT implant planning.

AI in maxillofacial prosthetics

The need for maxillofacial prosthetics was formally recognised during the 1950-80 period when there was a demand for prosthesis from patients with intra oral and extra oral defects. Most of the acquired defects were caused due to cancer and accidents. The demand was for prosthesis and hence, maxillofacial prosthetics got integrated to prosthodontics. Prosthodontists felt that there is a need for formal training in maxillofacial prosthetics (MFP). Awareness of MFP was very limited amongst dental and medical professionals. Majority of the patients were also unaware of MFP even though they were badly in need of it. Financial returns were not attractive and recognisable academic positions were not available in institutions. Between 1980 -2000 many short-term programmes were conducted by dental colleges, speciality hospitals and armed forces health centres. This was mainly happening in the western world but in India only few people were engaged in MFP practice out of personal interest. During this period, osseo integrated implants have shown their presence and which has become an advancement in MFP. In the surgical front, micro, bone containing free flap reconstruction of the jaws created clinical interest because of the functional outcomes. After 2000 many innovations have happened. Quality of life of the surviving patient received greater attention and functional outcomes have become measurable. Advanced digital technology has come to the field viz. digital surgical design, digital surgical planning, additive manufacturing and digital functional assessment [24].

Advanced digital technology (ADT)

ADT has become quite familiar to the prosthodontist with the advent of CAD/CAM in the fabrication of fixed prosthesis. This system functions as AI but in the chronologic entry, ADT superseded AI. 3D printing to fabricate prosthesis, surgical guides and aligners is quite familiar to the dental professionals.

Digital surgical design

This indicates the use of technology to enhance surgeries. It allows advanced visualisation, refined instrumentation, making use of 3D printed surgical instruments, robotic surgical platforms and improved connectivity through telepresence. 3D printed surgical instruments reduce production time, can incorporate surgeon's customisation and compatibility with 3D printers. However, the quality of the instrument should be reliable and ergonomic.

Digital surgical plan

This system allows for importing images of the patient and the image can be manipulated according to the surgical design. This can be on the screen or a virtual artificial space that the user can interact with and provides realistic experience. Now these simulators are becoming popular in education, training and therapy [24].

AI powered organs

AI employs neural networks that simulate human neurons. These networks were tried in artificial eyes which could help individuals to see. Texts can be read from books and from smart mobile screens. These patients can identify faces. Artificial skin is in the developing stage and which can sense temperature changes. Artificial olfaction developed can recognise different smells which is originally intended for environmental monitoring and may find a place in patients who have lost their noses and wearing prosthetic noses [25]. (Figure 7,8).

Figure 7: Bionic artificial eye.

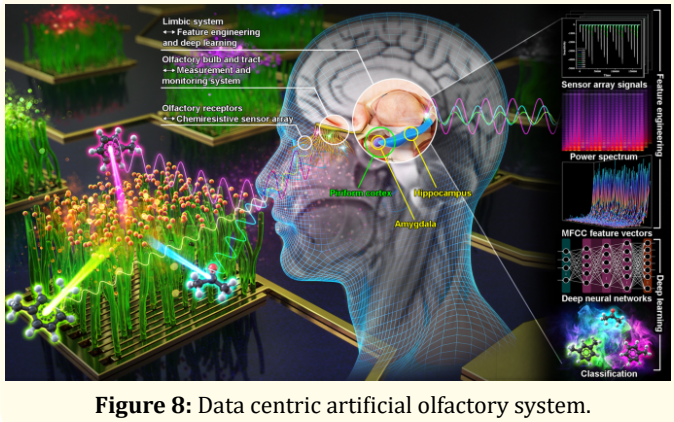

Figure 8: Data centric artificial olfactory system.

Awareness of AI amongst dental students and dental professionals

Gowdar IM et al. have conducted an extensive study using a questionnaire and made the following observations: 68% of the study population consisting of students and dentists was aware of AI and 58% believed that AI can cause major advancements. Diagnosis based on radiographs, maintenance of records, patient follow up and quality control of treatment are the areas where AI can be successfully employed. Answering to a question on whether AI will replace general dentists, 23% agreed. 95% had a fear that AI will possibly violate ethical principles [26].

In future, AI will have an important role and it has to be included in the dental course curriculum which incorporates critical thinking elements so that students can learn how to interpret data in their future research work and to use statistics effectively [27].

Many studies have raised the question of ethical challenges raised by AI viz. patients' rights', informed consent, patient as a consumer and rights of the patients on the stored data [28].

While undergoing the undergraduate course, dental professionals do not get adequate training and education on the basics and applications of AI and they do experience a lack of confidence. This is prevalent amongst the faculty members who got qualified years ago. Younger generations are exposed to AI either fully or partly from the school days onwards. There is a general consensus on the need for faculty focused training programmes on AI [29].

Patient's perception on AI

When asked about the knowledge of digital technology, majority of the patients rated it as average or above average and when asked about AI, only 47% gave the rating of average or above average. Disadvantage of AI listed by patients were – impact on work force needs, challenges to fiduciary relationship (legal and ethical obligation that is based on trust and confidence) between dentist and patient and increased dental care costs. A few patients had an opinion that there will be lack of empathy, data privacy challenges and neglect of education. Patients felt that x-rays will be diagnosed by AI, followed by dentist's assessment. Some patients noted that AI will perform better than the dentist whereas some others did not have the same opinion. Majority observed that dentistry will be benefitted from AI and they pointed out that AI will be included in the work flow within ten years. Patients felt that AI will bring in uniformity amongst dentists, improve diagnostics, better dentist-patient relationship and reduction in time taken for treatment. In fact, patients showed a positive attitude towards AI [30].

Discussion

AI created optimal programs for the functioning of intelligent agents which in due course of time were tested for their intelligence or mental ability. Alan Turing initiated the concept of machine intelligence and he formulated the testing tool which was later known as Turing test to evaluate the intelligent machine. John McCarthy was responsible for coining the term artificial intelligence and organised a formal workshop. This coincided with the beginning of research and development related to AI. AI has reached the present stage through advancements in computer hardware, algorithms and machine learning techniques. The history from 1961 to the present gives an array of tools like Unimate, the industrial robot, Eliza the Chatbot, Shaky the general purpose moving robot, Deep blue the chess playing robot that beat Kasparov, Kismat the robot that could make social and emotional interactions and Roomba the vacuum cleaning robot. Voice recognition feature in iPhone, Alexa and the innumerable number of tools and machines employed in technology are examples of AI initiated gadgets [31,32]. Specifically for dentistry preclinical training AI powered artificial humanoid robot was developed and which is a great advancement to dentistry. (Figure 9).

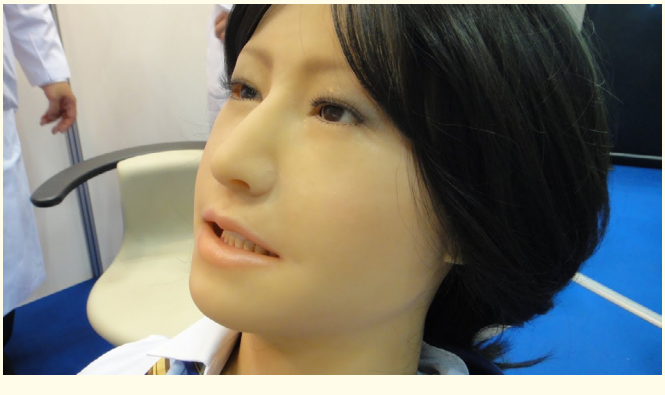

Figure 9: Dental training humanoid robot.

AI has gained an important role in dentistry and prosthodontics.

Some specific roles are as follows: 1. radiographs and intra oral scan images can be evaluated by AI and diagnose disease conditions 2. AI can help in formulating the treatment planning after evaluating patient data 3. Robotics can assist in tooth preparation and implant placement 4. AI powered virtual and augmented reality will help the patient in visualising the oral health, treatment and the results obtained 5. Clinic management skills like appointments and patient reminders can be done with AI. 6. Modern prostho labs are administered technically by AI for example the CAD/CAM system. In other branches of dentistry like periodontics, conservative dentistry, Orthodontics, Oral pathology and surgery also make use of AI in a great way [4].

Conclusions

AI was developed and got implemented in dentistry and prosthodontics within a period of seven decades and it has established its presence and usefulness. A stage has arrived that dental profession cannot avoid the association with AI because it has improved the quality of practice, streamlined the procedures, ensured predictability and precision, reduced the burden of decision making, brought in ease in administration and patient management. Education and training of dental students, professionals and patients gets improved both in clinical and academic areas. Unimaginable capacity of AI to handle huge quantity of data related to patient and updated information will definitely improve the quantity of service. However human supervision cannot be avoided to keep the confidence level of patients and professionals high. The replacement threat and ethical challenges will be taken care of in the future and hopefully a healthy coexistence might be resulted. Let us all be optimistic.

Figure credits

Figure 1. https://blog.sciencemuseum.org.uk/the-spirit-of-alan-turing/

Figure 2. https://www.wired.com/2011/10/john-mccarthy-father-of-ai-and-lisp-dies-at-84/

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