



APPLICATION OF ARTIFICIAL INTELLIGENCE IN PROSTHODONTICS : AN OVERVIEW

Dental Science

Dr. Mousumi Panda

Lecturer, Department of Prosthodontics and Crown & Bridge, Kalinga Institute of Dental Sciences, KIIT University.

ABSTRACT

Artificial intelligence (AI) being the evidence based uncontrollable innovation in this contemporary era has been refining every domain from space engineering to dentistry. Prosthetic dentistry is one of the branches of dentistry dealing with replacement and rehabilitation of lost maxillofacial structures with fixed and removable prosthesis or with biocompatible substitutes like implants helping to reinstate acceptable functionality of the orofacial region. The utilisation of knowledge engineering has made the decision making process uncomplicated and rapid by invigorating human brainpower into the machines that are programmed to think like humans and impersonate their activity, so patients are more agreeable and healthcare practitioners are further self-assured regarding their management. Artificial Intelligence has established evidence to be of advantage in the discipline of dentistry. The ensuing analysis highlights the contemporary technology of AI in dental prosthetics and its effectuality in diagnosing and fabricating more patient-specific prosthesis. Henceforward, AI based extensive care approach is expected to have high standard patient care and assist researchers to understand and manage diseases to a greater extent. Even though misinterpretations and definite impediments regarding AI prevails, it still continues to thrive due to its advantages in providing precision.

KEYWORDS

Artificial intelligence, Prosthodontics, Digital dentistry; Telemedicine; Nanodentistry

INTRODUCTION

Technology has been undergoing substantial change in the previous decade forcing mankind to develop a way of life which is fast-moving and controllable at the fingertips.^[1] In health sector, AI has become evident as a revivifying captivating mechanism as preventive measures and probability of infection have demanded development of non-invasive and simple approach for patients.^[2] Prosthodontics or the dental prosthetics plays a significant role in dental sciences and has an overall impact on the success and reformation of different stages of human life.^[3] The importance of fabricating the dental prosthesis is due to various reasons. First, compromise on the physical, mental and emotional health due to missing tooth structure. This absence creates problems related to chewing capabilities (or mastication), which eventually results in avoiding and altering an individual's food habits.^[4] Secondly, lack of teeth results in isolation due to fear of social acceptance. Since every individual desires proper aesthetics, teeth with its associated soft tissue, it plays an essential role in socializing.^[5] Lastly, the presence of teeth in the oral cavity helps maintain proper tongue position and placement of lips and cheeks, thus imparting suitable shape to the facial structures.^[6] Conventional diagnostic methods are limited to human intelligence and the usage of visual-tactile examination for diagnosis.^[7] Due to the increase in elderly patients within the population because of increased life expectancy, there is a greater prevalence of partial edentulism among adults. Edentulous spaces, replacement of lost hard and soft tissues, aesthetics, loss of function and support of the orofacial structures, interim prosthesis are few indications.^[8] Apart from the outcome of prosthesis, the procedure also exerts influence on the prognosis of residual ridge and abutment teeth. Indispensable activities such as mastication, swallowing, cognitive functions and pronunciation also depend upon dental prosthesis design. The concept of AI was introduced by John McCarthy, a mathematician from Dartmouth University in 1956 at a workshop, which credited him as the father of Artificial Intelligence.^[9] Richard Bellman in 1978 defined Artificial Intelligence as "The automation of activities associated with human thinking abilities, which includes learning, decision making and problem solving". This contrivance has made immense invasion in dentistry in the past decade especially during COVID-19 phase bringing a change in the way of practicing dentistry by reducing the inaccuracy and increasing the precision.^[10] AI has been of assistance in initiating prompt clinical solutions, keeping up the patient records digitally and processing them with the help of data-driven analysis, algorithms and machine learning.^[11] The fundamental aspects of AI commonly incorporated in dentistry are artificial neural networks (ANN), Machine Learning (ML), fuzzy logic, telemedicine, CAD/CAM, Nanodentistry, Digital Smile Designing & Dynamic navigational implant placement.^[12]

1. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural networks are particularly interrelated system inspired

by biological nervous systems.^[13] It has ability to think like human brain and interpret diseases based on the up to date data. The concepts of ANN in dentistry would help in rapid decision making and extraordinary memory useful in any time correlation.

2. MACHINE LEARNING

It correlates with the potential to process data attained through a specified recognition sensor or input tool according to a preestablished learning algorithm.^[14] This aids in devising an artificial neural network.

3. FUZZY LOGIC

Introduced by Lothfi A. Zadeh in 1962, it is the discipline of concept of human reasoning, thinking and inference that perceives and applies real-life occurrence to interpret detection and consequence.^[15] The idea supporting this is to deal with human reasoning potential that may not be accurate, precise and exact all the time. This can be an potent mechanism incorporating permutation and combination of data to generate faster results and design a human makeover when opting a relevant management for a particular case.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN DIFFERENT FIELDS OF DENTISTRY

AI is precisely applied to diagnosis, decision-making, treatment planning, and prediction of treatment outcomes.^[16] Artificial intelligence systems can perform tasks commonly associated with human cognitive functions such as interpreting speech and identifying patterns. Various benefits include: A. Automation: AI is used to automate anything ranging from tasks that involve extreme labor to the process of recruitment. AI application tools help to free employees from tedious manual tasks and allow them to focus on complex tasks.

B. Increased productivity: AI is being used to manage highly computational tasks that require maximum effort and time.'

C. Smart decision making: AI makes complex situations most simple and

D. Solve complex problems: AI helps in diagnosing complex medical conditions.^[17]

With rapid developments in the field, AI studies, which have started to radically change the sectors, will inevitably transform dentistry. The purpose of this section is to review the current and potential uses of AI applications in the field of prosthodontics.

REVIEW METHODOLOGY

Research articles based explicitly on the implementation of AI in dentistry have been extracted from various reputed sources, namely Google Scholar, Pub-Med, Springer and Scopus. Articles related to prosthodontics have been filtered out from the vast collection of papers. These articles have been critically analysed and included in

this review work. The review showed different application areas, data generation, training of AI model, accuracy and the advantages. A section is also included for discussion of current limitations and future scope for AI in prosthodontics.

INTRODUCTION OF AI

AI is modern technology based on replicating human intelligence and activities with the help of computer algorithms. It is a form of data-driven mathematical model. The model is trained on the previously available data, which enables the capabilities of predictions. The digitalized data is increasing day by day in the present time and helps in the training of AI models to generate more accurate results. AI model is similar to the neural network of the human body. Also, the model is referred as ANN, which stands for Artificial Neural Network.^[18]

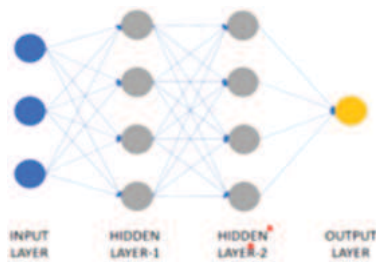


Figure 1: A schematic of ANN model.

AI model consists of mainly three layers (Figure 1)^[19]. The first layer is the input layer from which parameters are given in the model. The next layer is referred as the hidden layer consisting of neurons. The third layer is the output layer. In the process of training, the model is provided with training data. This data helps the model to establish a mathematical relationship in the input and output parameters. This trained model is further optimized on the testing dataset for more accurate results. Once the model is completely optimized, it is ready for practical predictions.

AI IN PROSTHODONTICS

Prosthodontics is the dental speciality about the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, support, esthetics, and well-being of patients with clinical status correlated with missing or deficient teeth and/or maxillofacial tissues by using biocompatible substitutes. AI in Prosthodontics is mostly concerned with diagnosis, treatment and fabrication of removable and fixed partial dentures, implant surgeries, and maxillofacial prosthesis; also used to select the shade of the prosthesis.^[20]

A. Removable and Fixed prosthesis- The digital automation of impression-making and also intraoral scanning techniques have supported the prostheses fabrication with absolute precision.^[21] Also, a 3D face scanning system supported in creating dental prosthesis can be a treatment substitute compared to conventional methods. Clinical environments continually change, therefore maintaining a skeptical approach to its output is vital.

B. Implantology- The implementation of AI in implantology puts forward the possibilities to integrate both AI and implantology and advance prosthetics hereafter. With the development of implantology, limitations of fixed and removable prosthesis can be resolved as they come up with an edge of being more resistant to dental diseases, preserving residual ridge, and providing better support in distal extension cases. In a study by Lee J and Jeong S, with the deployment of a convolutional neural network implants with the help of panoramic and periapical radiographs, it was concluded that the deep CNN model can be a helpful aid in classifying implant systems with almost equal or greater accuracy compared to humans.^[22]

C. Maxillofacial prostheses- Ackerman in the year 1953 defined maxillofacial prostheses as the aspect of dentistry that repairs and artificially replaces segments of the maxillofacial structures ensuing injuries or surgical intervention.^[24] Maxillofacial prosthodontics is a subspecialty of prosthodontics that relates to rehabilitation of patients with defects or disabilities that were present congenitally or developed due to disease or trauma. This prostheses are indicated for cosmetic and psychosocial reasons and for replacing structures to reinstate habitual oral functions like swallowing, speech,

and mastication. An impression of the entire face and the defect site is vital but the problems associated with these procedures are discomfort for patients, chances of material engaging in undercuts, difficulty in breathing, soft tissues may be distorted, time-consuming etc. Due to improvements in the technology sector, computerized three-dimensional data processing can procure complete facial morphologic assessment by using a non-contact 3D laser morphological measurement system.^[25]

Maxillofacial reconstruction involves implanting artificial substitutes for intraoral and extraoral structures such as the eyes, ears, nose, maxilla, mandible, palate, etc. The success of any prosthesis depends on its retention as it improves comfort and confidence in the patient. Various methods used to improve retention are adhesives, implants, eyeglasses, and combinations. Over the past two decades, osseointegrated implants have been used for augmenting retention in the craniofacial regions. Various systems that are currently available in the market include bar and clip systems, magnets, mushroom, and ball retention methods. So these prostheses can now be fabricated using digital technologies. The modeling of maxillofacial prosthesis utilizing CAD/CAM technology starts with imaging techniques that record the patient's soft and hard tissues. Software is subsequently used to transform this data into a Rapid Prototyping (RP) model.^[26] Subsequently, utilizing reproduction techniques, the RP models are transferred into wax directly or in acrylic resin. The silicone elastomer prosthesis can be built from the cast. This approach requires less time than the conventional approach.

D. Computer- Aided Designing and Computer-Assisted Manufacturing (CAD-CAM)- Additive manufacturing, subtractive manufacturing, 3D printing are commonly used CAD-CAM technology for fabrication of prostheses.

CAD-CAM SYSTEM HAS GOT 3 CONSTITUENTS:

(a). Digital impressions: Collection of data of prepared teeth and adjoining tissues from health professionals to be converted into visual impressions which are then transferred to the laboratory. (b) Designing the final prosthesis and preparing for milling. (c). Milling phase: After the design of the final prosthesis, fabrication of the prosthesis is done by milling appropriate restorative material.

(a). Digital impressions/scanners:-Standard impression methods are the perfect system of recording prepared teeth and adjacent dental tissues. Regardless of evolution in material sciences, there are many flaws of impression materials. Up to the present time we do not have one common ideal impression material convenient for all sorts of procedures. With progress in the technological sphere, intraoral scanners came about to deal with shortcomings of the standard impression procedure.

ADVANTAGES:-

- No need for conventional impressions, so comfortable for the patient.
- No need for any impression material, or disinfection control protocol.
- Fewer chances of error when compared with conventional impressions.
- Fewer laboratory procedures like pouring impressions.
- Can review preparations immediately after scanning, if required can modify preparation and rescan
- Data collection of impression can be immediately transferred to dental laboratory.

DISADVANTAGES:

- Trained or skilled persons are required
- More expensive.

(b). Designing final prosthesis- Subsequent to receiving the scanned impression of required images from the dental surgeon, in the laboratory the data are processed by design software. Final 3D image can be designed which exactly looks like provisional restoration. The designed final prosthesis can be transferred to concerned health professional for approval, if required the final design can be modified. After designing the final prosthesis, the data is transferred to the special milling device.

3.Milling phase-After steps 1 and 2 where design is completed, data is transferred to the centralized milling/production centre.

Suitable restorative material can be milled by using additive technique, subtractive technique or 3D printing technique.

ADVANTAGES:

- No materials required for procedures like die materials, investment material.
- Time saving because of no casting procedures
- No human errors during casting procedures which leads to casting failures.
- Precise final restorations can be obtained.
- Time-saving.

FUTURE PROSPECTS OF ARTIFICIAL INTELLIGENCE

In coming times, AI will impart new hope for mankind with further development in every angle of technology at its best. Hybrid intelligence is making way to be the one that will be designing a new era of the blend of human and machine intelligence. The usage of a hybrid intelligent image fusion system to merge multimodal images for better diagnosis and treatment planning will become widespread.^[27] Even though the AI models used have high favourable outcome, it is still indispensable to substantiate the general applicability and dependability of these prototypes using requisite illustrative images from numerous institutions prior to using these models in clinical applications. AI digital systems have undisputably changed future predictions and development in the practice of dentistry. It is obvious that these networks play an important role in the decision-making and minimizing of systematic errors during the execution of treatment planning and also in advanced research.

LIMITATIONS AND FUTURE SCOPE

AI is heavily dependent on datasets. These datasets should be appropriately classified and filtered for excellent model training. In the present scenario, the medical sector has started digitalizing the diagnosis and reports but still a long way to go for accurate data that can be used in model training. Future in the AI implementation is exciting as this provides a decentralization in the process of treatment as AI enabled medical professionals can do remote treatment in a better way. Accuracy of diagnosis of disease will be higher in the future as AI will make a prediction that can be integrated with the human reasoning power to enhance the possibilities of proper diagnosis.^[28]

CONCLUSION

In the review process, it has been perceived that the use of AI in prosthodontics is increasing at an exponential rate. The results of the implementation are similar and sometimes better than humans. AI can be seen as a potential tool in every aspect like classifying denture fixtures, extracting marginal lines and minimizing human error involved in cementation of implants. Every study found a higher accuracy in the prediction results compared with humans. As with any newer advancement that is happening across the globe there is always a divide among professionals about the active role of technologies in healthcare settings. However, the future in AI implementation is exciting as this provides a decentralization in the process of treatment.