International Journal of Advances in Medicine
Pareek M et al. Int J Adv Med. 2022 Mar;9(3):367-370
http://www.ijmedicine.com
pISSN 2349-3925 | eISSN 2349-3933
DOI: https://dx.doi.org/10.18203/2349-3933.ijam20220444

Review Article

Artificial intelligence in prosthodontics: a scoping review on current applications and future possibilities

Mitali Pareek[1]*, Brahmansh Kaushik[2]

[1]Mahatma Gandhi Dental College and Hospital, Jaipur, Rajasthan, India
[2]Department of Mechanical Engineering, Indian Institute of Technology Jammu, Jammu and Kashmir, India

Received: 10 January 2022
Accepted: 02 February 2022

***Correspondence:**
Mitali Pareek,
E-mail: mitalispareek@gmail.com

ABSTRACT

Artificial intelligence (AI) is the data-driven disruptive technology of modern times. AI is reforming every field from space science to dentistry. Bio-medical provides various advantages over conventional diagnosis, treatment planning, patient documentation and management. Every field is implementing AI for the ease of both doctors and patients. In this present work, the review was done for the implementation of AI in prosthodontics. Prosthetic dentistry or prosthodontics is one of the branches of dentistry, mainly deals with replacement and rehabilitation of missing teeth with the help of fixed and removable prosthesis or with biocompatible substitutes like implants. In addition, it also helps to restore proper soft and hard tissues of the mouth, thereby improving the overall health status of the oral cavity. The following review highlighted the present-day technology of AI in dental prosthetics and its efficacy in diagnosing and constructing more patient-specific prosthesis. In conclusion, it is seen that AI is twin fold technology having both applications and limitations in dentistry.

Keywords: Dentistry, Artificial intelligence, Bio-medical and AI, Prosthodontics

INTRODUCTION

Prosthodontics or the dental prosthesis sector plays a significant role in dental sciences and has an overall impact on the success and reformation of different stages of human life. 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.[1] This absence creates problems related to chewing capabilities (or mastication), which eventually results in avoiding and altering an individual's food habits. Secondly, lack of teeth results in isolation due to fear of social acceptance.[2] Since every individual desires proper aesthetics for every part of body and teeth with its associated soft tissue, it plays an essential role in socializing. 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. Conventional diagnostic methods are limited to human intelligence and the usage of visual-tactile examination for diagnosis.

Acrylic dentures in the form of removable or fixed partial dentures are dental prosthesis fabricated to replace missing teeth in patients who desire to get better functional and aesthetic form. 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.[3] In the next 15 years, partial edentulism individuals could rise to more than 200 million in the United States alone.[4] Edentulous spaces, replacement of lost hard and soft tissues, aesthetics, function and support of the orofacial structures, interim prosthesis are few indications for using partial dentures in adults.[5] Besides the outcome of prosthesis, fabrication of dentures also determines the prognosis of residual ridge and abutment teeth.[6] Essential functions such as mastication, swallowing, cognitive functions and pronunciation also depend upon dental

prosthesis design.[7] Currently, they are fabricated by dentists manually using clinical knowledge and experience.

Review methodology

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

These articles were 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 was 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 a 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 an artificial neural network.

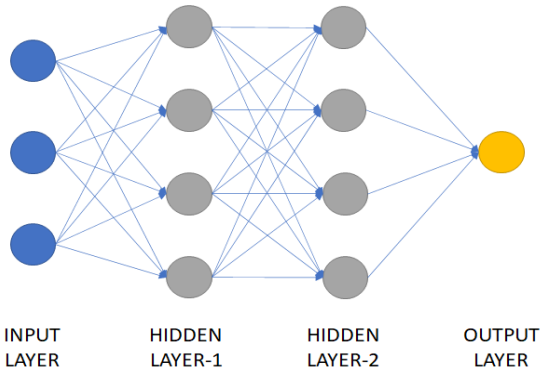

Figure 1: A schematic of ANN model.

AI model consists of mainly three layers. Figure 1 shows a typical ANN model. 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 (Figure 1).

AI in prosthodontics

Prosthetic dentistry is the art and science of dentistry that deals with the diagnosis, treatment planning, rehabilitation and preservation of the oral structures function, comfort, aesthetics and health of patients with clinical problems associated with missing or deficient teeth and oral and maxillofacial tissues. Prosthodontics mainly focuses on the treatment and fabrication of removable and fixed dental prosthesis, preparation of finishing margins alongside the tooth for better extension and fitting of the prosthesis, implant procedure and construction of a maxillofacial prosthesis. Maintenance of proper maxillomandibular relations, selection of tooth shade for better aesthetics. AI can be very advantageous in various methods of a treatment protocol. Several applications are discussed in this section.[8]

With the advent of implantology, various limitations of the fixed and removable prosthesis can be solved. Implants provide the advantage of being more resistant to dental diseases, preserving residual ridge and providing better support in distal extension cases.[9] Implants are widely used in dentistry to replace the missing tooth or for the entire mouth rehabilitation. Acceptance of implant prothesis has been increased in recent years due to better aesthetics and stability. There are overall 4000 dental implants that are marketed worldwide. They vary in treatment techniques and structure. A dentist needs to recognize and classify the implants correctly to avoid chances of replantation and repair due to mechanical and biological complications. CAD-CAM and panoramic radiographs are the primary methods to classify the implant structure.

Hong et al conducted a study with the deployment of a convolutional neural network (CNN) from deep learning for determining the efficacy of CNN models to classify the implants with the help of panoramic and periapical radiographs. The selection of patients was made from the year 2010 to 2019 who underwent implant surgery. Periapical and panoramic radiographs of these patients were obtained. The total images that were extracted were 10,770. The study included the classification of three implants, namely Osstem TSIII, Dentium Super line and Straumann BLT implant systems. The data were divided into training, tested and validation data set. Google Net inception v3, CNN model was used to predict the outcomes. The result was compared with the 3 expert periodontists after statistical analyses. The area under curve (AUC) of deep CNN with the help of a combination of both panoramic and periapical radiographs was 0.971, while that of prosthodontists was 0.925. When the CNN model was deployed using panoramic images, the AUC reported as 0.956 and prosthodontist was 0.891. When periapical radiographs were taken into account, the deep CNN model and prosthodontists both showed AUC as 0.979. From the results of this study, it can be concluded that the deep CNN model can be a helpful aid in classifying implant systems with almost equal or greater accuracy compared to humans.[10]

The cementation of implants prosthesis in the mouth may result in several problems when conventional CAD-CAM systems are used. Errors can be due to many reasons such as positional errors, cementation errors and occlusal or interproximal adjustment with an abutment. Henriette Lerner et al proposed an AI model to minimize these errors. This AI model was to help in the fabrication of fixed implant prosthesis using monolithic zirconia crowns. The deployment of the AI model to assist in the detection of subgingival margins of the abutment. Also, this model helped in increasing the dentist's focus on tooth preparation and maintaining interproximal and occlusal contacts. This ease was to reduce errors and time usage. For the study, the patient recorded from 2016 to 2019 was used in the study with zirconia implant prothesis in posterior teeth. The gender diversity of the study was with male to female ratio was 7:11 in 90 patients. Total 106 implants were part of this study. Data sets for the training purpose of AI models comprised intraoral scans, radiographs, photographs and CAD scenes (images). The promising results were observed with the usage of AI model in the fabrication of zirconia implants for the posterior teeth with a survival rate of 91% and success rate of 93%. Since results from the AI model showed a high survival and success rate, which showed the proficiency of the model to be integrated into this field.[11]

Traditionally, tooth margin preparations during the fabrication of fixed dental prosthesis were usually done manually with the help of a handpiece and a variety of burs by dental specialists. Proper extension and contour of the marginal line around the teeth helped keep the prosthesis in position and provided a healthy environment and protection to gums and periodontal tissues. These methods required more excellent technical skills and time. The idea was to remove the tedious manual efforts and errors. A deep learning model study was conducted by Zhang et al to extract marginal line with precision. This study included 380 dental preparation models. Sparse octree (S-Octree) was used as a CNN model to extract the data. Sparse point cloud with the labels was made with the help of the processing of dental preparations. Eighth depth octree structure was developed for the study. The data was divided into training, verification and test data sets. CNN models were trained by marking the labels on dental preparations. In the study, back projection and boundary extraction methods were implemented, tooth preparation line was extracted that overcomes the disadvantages of manual practice. The average accuracy reached up to 97.43%. This higher accuracy showed the capabilities of AI for overcoming manual errors made it a good option for implementation.[12]

Classification of dental arches helped in maintaining standardized outcomes of proper design, description of edentulous space within the arch, further aiding in improved communication between the dentist, intra-operator consistency and ease of treatment planning. Currently Kennedy's classification was mainly used for the classification of edentulous spaces and arches.[13,14]

A methodological study conducted by Takahashi to develop an AI model with the help of CNN for classification of dental arches to assisted in the fabrication of dentures.[15] Data used for the study was collected in the form of oral photographic images, 1184 of total including 748 of the maxillary arches and 438 of the mandibular arches. Types of arches included complete edentulous, arches with posterior tooth loss, bounded edentulous space and intact arch. The data set was divided into training data set with 1016 images (85%) and testing data set with 168 images (15%). TensorFlow and Keras were used for the development of the CNN model. With the help of autonomous learning procedures by computer, classification of training data set was done based on learning. Prediction of dental arches was made after the learning procedure was completed. Percentage of correct prediction (PCP) was recorded. Median PCP results in the maxillary arch were 100% (edentulous), 99.4 distal extensions missing, 97.5 intermediate missing and for intact teeth it was 97.9%. The mandibular arch had 100% for edentulous, 99.3% for distal extension and 98.8% for an intermediate missing and intact tooth. Learning performance was assessed with the help of AUC. It was recorded as 0.98 which was close to 1. High diagnostic accuracy was also observed in the cases of maxilla as 99.5% and for mandible 97.5%. Values indicated that there was a future possibility of AI models to assist the clinicians in classifying arches and thus help high-quality de-sign RPD for each patient.

Limitations and future scope

AI was heavily dependent on datasets. These datasets should be appropriately classified and filtered for excellent model training. The limitations present here were that most data were in paper format and due to lack of awareness in follow up treatment, data consolidation was not done correctly. In the present scenario, the medical sector had 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 was exciting as this provided a decentralization in the process of treatment. AI enabled medical professionals to 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 diagnosis to enhance the possibilities of proper diagnostics.

CONCLUSION

In the review process, it is seen 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.

Researchers are taking advantage to form AI for better oral health and the overall health of individuals.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Reissmann D, Schierz O, Szentpétery A, John MT. Improved perceived general health isobserved with prosthodontic treatment. J Dentist. 2011;39(2):326-31.
2. Reisine ST, Fertig J, Weber J, Leder S. Impact of dental conditions on patients' quality of life. Commun Dentist Oral Epidemiol. 1989;17(1):7-10.
3. Abt E, Carr AB, Worthington HV. Interventions for replacing missing teeth: partially absent dentition. Coch Database Systemat Rev. 2012;2:003814.
4. Campbell SD, Cooper L, Craddock H, Hyde TP, Nattress B, Pavitt SH, et al. Removable partial dentures: the clinical need for innovation. J Prosthet Dentist. 2017;118(3):273-80.
5. Bohnenkamp DM. Removable partial dentures: clinical concepts. Dent Clinic North Am. 2014;58(1):69-89.
6. Tada S, Allen PF, Ikebe K, Zheng H, Shintani A, Maeda Y. The impact of the crown-root ratio on survival of abutment teeth for dentures. J Dent Res. 2015;94(9):220-5.
7. Inomata C, Ikebe K, Okubo H, Takeshita H, Mihara Y, Hatta K, et al. Dietary intake is associated with occlusal force rather than number of teeth in 80-y-Old Japanese. JDR Clin Trans Res. 2017;2(2):187-97.
8. Revilla-León M, Gómez-Polo M, Vyas S, Barmak BA, Gal-lucci GO, MutluÖzcan WA, et al. Artificial intelligence models for tooth-supported fixed and removableprosthodontics: a systematic review. J Prosthet Dentist. 2021.
9. Jivraj S, Chee W. Rationale for dental implants. Br Dent J. 2006;200:661-5.
10. Lee J, Jeong S. Efficacy of deep convolutional neural network algorithm for the identification and classification of dental implant systems, using panoramic and periapical radiographs: a pilot study. Medicine. 2020;99(6):20787.
11. Lerner H, Mouhyi J, Admakin O, Mangano F. Artificial intelligence in fixed implant prosthodontics: a retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posteriorjaws of 90 patients. BMC Oral Health. 2020;20(3).
12. Zhang B, Dai N, Tian S, Yuan F, Yu Q. The extraction method of tooth preparation margin line based on soctree cnn. Int J Numer Method Biomed Engineer. 2019;35(10):3241.
13. McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH, et al. Classification system for partial edentulism. J Prosthodont. 2002;11:181-93.
14. Al-Johany SS, Andres C. ICK classification system for partially edentulous arches. J Prosthodont. 2008;17:502-7.
15. Takahashi T, Nozaki K, Gonda T, Ikebe K. A system for designing removable partial den-tures using artificial intelligence. Part 1. Classification of partially edentulous arches using a convolutional neural network. J Prosthodont Res. 2021;65(1):115-8.

Cite this article as: Pareek M, Kaushik B. Artificial intelligence in prosthodontics: a scoping review on current applications and future possibilities. Int J Adv Med 2022;9:367-70.