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Artificial Intelligence: A neoteric reach in Periodontics

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ABSTRACT:

Periodontal disease diagnosis is the fundament point for the accurate treatment planning. Precise diagnosis requires experience and knowledge of the dentist, But it may vary from each dentist to the other dentist causing errors in diagnosis and treatment planning. To overcome these limitations, an emerging technology like Artificial Intelligence(AI) is of immense use in the field of periodontics. In this technology, an Artificial Intelligence driven machine can be utilized for

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performing the human tasks perfectly. This review is an attempt to describe various current concepts and future applications of AI in periodontology.

INTRODUCTION:

Periodontal disease (PD) is a wide spectrum of inflammatory condition affecting the teeth: gingiva, cementum, periodontal ligament, and alveolar bone. Periodontal disease is often invoked by an uncontrolled inflammatory response and bacterial colonization which causes disintegration of the periodontium and causes periodontitis when there is impairment of the host inflammatory response.[1]

When left untreated periodontitis acts as a putative risk in conditions like cardiovascular disease, respiratory diseases, cerebrovascular conditions, endocrinal disorders like mainly diabetes, any hormonal imbalances, obesity, pregnancy complications, and osteoporosi.[2]

Precise diagnosis is the major challenge in periodontitis cases. The traditional diagnostic methods currently in practice are assessment of clinical and radiological features using probes and 2-dimensional and advanced 3-dimensional radiographs. But these techniques have limitations like poor intra and inter examiner reliability. These limitations in diagnosis and treatment planning make it a necessity to adopt a tool which uses AI technology.[3]

A pandemic situation like Covid has completely changed the workstyle of the dentist. The dentist as well as the patients found it as a challenge for direct examination of the patient and diagnosis and treatment planning by the dentist, especially for a periodontist which requires both clinical and radiographic examination to conclude a diagnosis. In such a scenario an ingenious technology like AI would be a boon for all the periodontal diagnosis, treatment planning.[4]

HISTORY

Initially AI was described by Turing simply as "Machines thinking". He thought that the human competence to investigate a solution for a problem and make a decision is mainly dependent on the information which is available regarding the problem and its analysis through logical thinking and interpretation of the data in the mind. Machines also can do the same task by using machine intelligence.[5]

Though the term AI was coined in 1965 by John McCarthy, it was Newell and Simon in 1955 who developed "The Logic Theorist" which is considered as the first AI program. It is the simulation of human intelligence process by the computer systems.

Machine learning (ML) and expert systems are the two opposite approaches which were developed in the 1980's.

Machine Learning: ML solves the problems by the knowledge which is gained by previous learning and experiences.

ML is further categorized into supervised learning which has high accuracy, semi-supervised learning with mid-level accuracy and unsupervised learning with low level accuracy.

Supervised learning: It is a type of machine learning where in, the labeled data is given to the model to train the model on the

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labeled data to make accurate predictions based on the input-output pairs. [6]

Semisupervised learning: It utilizes both the labeled and unlabeled data to make the predictions.

Unsupervised learning: Unlike the Supervised learning the model learns patterns and relationships in unlabeled data without precise output labels.[7]

Expert systems resembles the decision-making process of humans but it needs human experts to input all the data priorly.[8]

Deep learning: Deep learning is a subset of ML which involves both supervised and unsupervised learning.

Neural networks are the subset of deep learning. These are regarded as the pillars of deep learning. The most important types of neural networks which are applied in periodontics are artificial neural networks (ANNs), convolution neural networks (CNNs).

ANN (Artificial Neural Network): A computational model inspired by the human brain's neural structure, used in various machine learning tasks for pattern recognition and decision-making.

CNN (Convolutional Neural Network): A type of deep learning neural network designed to process and recognize visual data, commonly used in image and video analysis tasks.[9] Since the first publication of CNN in the early 2010's there has been a rise in the application of this tool in periodontics.[10]

APPLICATIONS:

AI can be applied in periodontics, wherein the periodontist team up with the scientist to develop and program algorithms that can be used as an assessing tool to analyze the clinical and radiological findings to establish a decisive diagnosis by reducing the errors and also for the definite treatment planning for a better patient care.[11]

Periodontitis is one of the most prevalent diseases affecting the soft and hard tissues of the periodontium, which may gradually lead to tooth loss if prompt diagnosis and treatment planning is not done. As discussed earlier due to the limitations in early detection and treatment planning and low reliability. As the clinical evaluation is still based on the skills and experience of the periodontistis there are high chances for a misdiagnosis and treatment planning.[12]

Haptics-based virtual reality periodontal training simulator

Luciano et al was the first person to develop the first haptics-based dental simulator developed exclusively for Periodontics. This simulator helps trainees to develop the required skills to diagnose and treat periodontal diseases.

The two kinds of dental simulators available are:

- Manikin-based simulators which includes a physical model similar to the patient's head and mouth on which dental procedures can be performed using real dental instruments. These models will require frequent replacement and maintenance cost is also high. As this does not provide the tactile sensation.
- Haptics-based simulators that employ a haptic device and virtual models of a human mouth for dental procedures practice. These are more

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cost effective as it doesn't require frequent replacement. It also provides tactile sensation to the trainee.

The application of virtual reality and haptics technology in periodontics allows the clinician to diagnose and design a perfect treatment plan for the periodontal problems. This is possible because the operator can visualize the 3-dimensional virtual human mouth and tactile sensations can be felt while touching the tooth, gingiva and calculus which is performed with virtual dental instruments. As the periodontal disease diagnosis and treatment mainly depends on the tactile sensation, the application of haptics in periodontics is undeniable. Further recording and playback of the trainee's performance was also incorporated into this in 2007 by Steinberg et al. Gockel et al in 2002, have attempted to incorporate haptics to simulate teeth cleaning procedures.[13]

DIAGNOSIS OF HALITOSIS:

Volatile Sulphur compounds which are the main culprits in causing halitosis are mainly produced by the bacterial metabolism in the oral cavity. Out of various volatile Sulphur compounds in the oral cavity hydrogen Sulfide and methyl mercaptan are the most abundant due to their high volatile nature and low odor threshold. Detection of these VSC's is the main diagnostic feature of halitosis.

Since the subjective organoleptic method of detection for VSC's has limitations, other breath analyzers came into existence. The detection of halitosis based on only analyzing VSC's is not valid as, there are conditions where halitosis is exists even in the absence of VSC (Volatile Sulphur Compounds), and conditions where halitosis is caused by non-Sulphur Volatile compounds, biomarkers of systemic diseases.[14]

A non-invasive artificial olfaction technique which can assess the full spectrum of oral volatile compounds has been developed. It comprises of an array of nano-materials based sensors that can assess the composition of the oral breath using analysis software and database of breath patterns and then a pattern recognition application is used. Later a decision tree classifier analyses the breath and determines whether the subject suffers from oral or extra oral halitosis. If the halitosis is not originating from oral cavity, it can analyze the association with the systemic diseases. In 2017, 20 functionalized nanomaterials-based sensors were designed to successfully distinguish between 17 different systemic diseases by analyzing the exhaled breath with 86% accuracy.[15]

Artificial gas mixture composed of target VOCs (Volatile Organic Compounds) / VSCs can be utilized in preclinical experimental assessments to train the sensors for increased sensitivity.[16]

Differentiation between aggressive and chronic periodontitis:

In 2017, in a hypothesis a Support Vector Machine classifier was able to distinguish between periodontal health, aggressive periodontitis and chronic periodontitis patients by using a panel of 40 species.[17]

Automated segmentation of gingival diseases from oral images:

In 2017, a machine learning classifier was reported that could differentiate between inflamed and healthy gingiva. In this an oral imaging device has been used to record the fluorescence that is emitted from biomarker porphyrin after irradiation with light of 405-450 nm wavelength. Plaque was displayed in orange and yellow shades but inflamed gingiva was displayed in magenta and red shades. ANN can be successfully used for periodontitis grading assessment according to the new classification and periodontal treatment planning.[18]

Correlation between oral diseases and systemic health:

Various studies have proved the association between psychological stress and the occurrence of periodontal disease. It is concluded that the level of stress hormone levels and anxiety have an impact on the periodontitis. The same has been proved in the study conducted by Vadzyuk et al. In his study he have used the neural networks to predict the risk of periodontitis in young people with psychological stress. Also, in the studies done by Rana, Yauney et al, in 2019, the correlation between systemic health and periodontal health was confirmed, which used an automated process that combined the aforementioned intra-oral fluorescent porphyrin biomarker imaging, clinical examinations and machine learning.[19]

Diagnosis and prediction of periodontally compromised teeth Using automated process:

A fully interpretable and completely automated method known as Deetal perio was used to diagnose the severity of periodontitis by using panoramic radiographs and Alveolar bone level as the landmark, by Lee et al in 2018. For this a prelabelled Periapical dataset was given, to predict and diagnose the periodontally compromised teeth. The predictive accuracy of the results obtained from this study were similar to that obtained by the certified periodontists.[20]

Diagnosis of periodontal bone loss using deep learning:

Deep CNN were used to detect periodontal bone loss using a panoramic radiograph and then compared this diagnostic accuracy with that of an experienced periodontist. The results concluded that that there was limited agreement with the dentists and it could be overcome by giving additional image inputs like peri apical radiographs and clinical data. The CNN has also showed lower sensitivity than dentist, when a high cut-off definition was used for periodontal bone loss. This sensitivity could lead to over detection of the bone loss and mislead the treatment plan.[21]

Applications in Implantology

- A systematic review by have concluded that AI models could be successfully incorporated for implant type recognition using Periapical and panoramic radiographs with an accuracy of 93.8% to 98%. Implant

success was also predicted by predicting the level of osseointegration by reducing the stress at implant-bone interface by 36.6% and for optimization of the implant designs based on the elastic modulus of the bone-implant interface.

- Mouhyi et al in 2020, used AI along with the CAD software for the fabrication of implant-supported monolithic zirconia crowns (MZCs) cemented to individual hybrid abutments. It reduces the cost of the prosthetic surgery possibility of errors and mainly saves the time of the dentist. The reported success rate was 99% and 91.3%.
- AI was also applied to assess the bone loss accurately and aid in the diagnosis of severity of peri-implantitis by using an automated system by Jun-Young Cha et al.
- In 2020 Nozaki et al used a deep learning-based object detection software to identify implant systems with the help of panoramic radiographs. This will help to overcome the limitation of the dentist to treat implant related issues, in case where the dentist is not aware of the implant system .[22]

ADVANTAGES OF AI IN PERIODONTICS:

As in any other field, AI have tremendous advantages in periodontics.

- Application of AI can guide in accurate diagnosis
- Helps in standardization of treatment protocol
- Reduces the errors in treatment
- Dental appointment coordination
- Time saving to the dentist.
- Manages patient documentation and insurance

DISADVANTAGES:

- It is expensive to set up
- The software must be updated frequently according to the latest requirements.
- Correct image input and clinical data has to be supplied to machine to give an accurate diagnosis and treatment plan.
- Ethical issues as the medical data is used for training
- All the tasks are performed by the computer machine without the medical knowledge. It is not comparable to the experienced professional.
- Patient dentist interaction would be completely lost.

FUTURE OF AI:

According to Yo-Wei Chen et al a comprehensive Care System was predicted which will consider the patient's history, analyses the patient's dental radiographs from previous appointments, and evaluates the planned treatment before each appointment. It will also assist the dentist to understand the patient preferences and then aid the dentist in diagnosing the problem and planning the treatment. It reduces the human error by giving feedback to the dentist during the procedures and predicts the outcome and prognosis of the treatment. In the future, electronic patient files and digital x-rays can be maintained in the

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dental colleges and clinics with the help of AI. Also 3D intra-oral scanning can be enabled for a distortion-free examination.[23]

CONCLUSION

Though the AI models for periodontology is still under development, in the future AI can be incorporated for a more accurate diagnosis and decision making, that aids in the improved patient care. Despite the limitations of AI, it may be successfully associated with the dentistry due to its precise treatment planning and helps to exchange huge data among the professionals.

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