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Review Article

Navigating the Digital Era: Artificial Intelligence in Modern Prosthodontics

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ABSTRACT:

The global rise of Artificial Intelligence (AI) can be attributed to its profound influence on scientific advancement and innovation. In the field of prosthodontics, the utilization of AI has seen a marked increase in recent years. AI technologies are employed for various purposes, including diagnosis, decision-making, prognosis, treatment planning, and outcome prediction. The incorporation of AI into prosthodontic practices has the potential to improve both the accuracy and precision of dental procedures. Nonetheless, the availability of limited datasets poses a significant challenge to its effective implementation.

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Introduction

The rapid digitalization across various facets of life has significantly eased living conditions. The ethos of working smarter, not harder, is deeply ingrained in every individual. If machines can be imbued with the capability to think and act like humans, it could potentially revolutionize numerous fields, leading to substantial reductions in manpower requirements and benefiting mankind immensely.[1]

Since the beginning of recorded history, the functioning of the brain has fascinated people, and various technologies have attempted to replicate it. Artificial intelligence (AI) is the result of years of effort to accurately imitate the workings of the human brain that could achieve results or tasks that need human intelligence.[2] The advancement of artificial intelligence (AI) within the 21st century has caused drastic upheavals in a variety of industries, with health-care standing out as a key beneficiary. AI is rising into health technology, revolutionizing medical administrations through predictive, preventative, individualized, and participatory approaches.

AI envelops distinctive computational concepts such as machine learning, deep learning procedures, and neural systems (Fig 1).[3] With machine learning, the system learns statistical patterns in a data set to predict the behaviour of new data samples. Machine learning systems offer a variety of algorithms and methods that are suitable for complex prediction tasks by recognizing and capturing statistical patterns in a data set.[2]

Neural network as the name suggests, uses artificial neurons to set the algorithm and works almost similar to the human brain. Neural networks are developed based on brain structure, and as the brain, they can recognize the pattern, manage data and learning.[3] The most important advantage of artificial neural networks is that this type of system solves problems too complex for conventional techniques and those that do not have an algorithmic solution or are too challenging to be used. They are helpful in various areas of medicinal science like diagnosis of diseases, biomedical identification, image analysis, and data analysis.[4]

Deep learning is a type of machine learning that utilizes the network with different computational layers to analyse the input data. Deep learning is also known as conventional neural network (CNN).[1] This subset of machine learning uses deep neural networks. The machine utilizes different layers to learn more about the data. The number of layers in the model represented the depth of the model.[3]

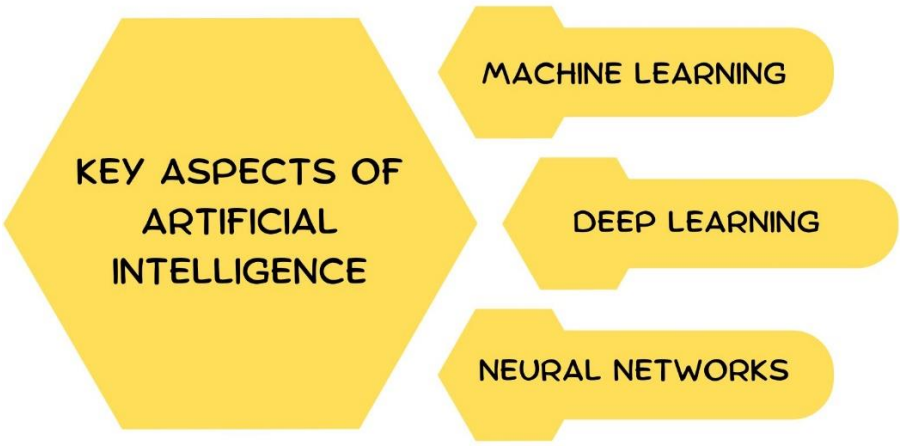

Fig 1: Schematic diagram of key aspects of Artificial Intelligence

Technological advancements have also brought significant changes in medicine and dentistry in the past decade. By utilizing AI, dental healthcare professionals can reduce the workload and the need for more staff, making it a valuable tool in the field.[5]

Machine learning-enabled decision support systems can utilize the vast amount of data in healthcare systems to provide optimal learning sources for healthcare practitioners. These systems can help sort out the complexities of clinical variabilities and increase diagnostic accuracy. The development of cloud computing, data processing, and the availability of massive amounts of data have led to the increasing adoption of AI in healthcare and dentistry. Radiology, for instance, has benefited from the use of a specific algorithm that aids in diagnosing and providing potential treatment options. AI has the potential to be utilized in several fields of dentistry, including prosthodontics, orthodontics, oral surgery, and periodontics for condition analysis and treatment planning.[6]

Indeed, AI has a vast potential to revolutionize the field of prosthodontics. Machine learning algorithms can analyse patient data and predict the best treatment plan for each individual patient based on their unique needs and conditions. For example, AI can be used to design and fabricate customized dental prostheses such as crowns, bridges, and dentures that perfectly fit a patient's mouth and function optimally.[7] This is particularly important in cases where patients have unique or complex dental structures that require a more personalized approach. AI can also aid in implant surgery by accurately planning the placement and orientation of dental implants based on factors such as bone density and proximity to nerves and blood vessels. This can help reduce the risk of complications and improve the overall success rate of the procedure. Overall, AI has the potential to greatly enhance the precision, efficiency, and effectiveness of prosthodontic treatments, ultimately improving the overall quality of care for patients.[8]

The present literature review study represents a valuable resource for dentists and dental analysts exploring the potential advancements of AI in prosthetic dentistry and oral implantology. With aging populations increasingly seeking high-quality and minimally invasive treatments, the integration of AI stands to enhance treatment outcomes significantly.

Application of AI in General Dentistry

- Scheduling dental appointment: Artificial intelligence allows the dentist to arrange an appointment without human intervention, track the progression of the disease, and do the routine chore of scheduling an appointment on time. This technique uses the fastest speed to complete routine tasks in dentistry.
- Proper Medication: AI provides information about the proper medication to a patient with the simplest way of treatment and informs patient the proper time of medication and the side- effects if one does not follow time.
- Communication: AI is applied directly to communicate with the patient and control all information systems in the hospital using different algorithms.[3]
- Detection of tooth loss: This technology automatically calculates the loss of patient teeth by using computer software and provides the cause of any disease in teeth and its best way of treatment.
- Monitor high-risk cases: AI easily monitors the high-risk patient and generates decisions within a couple of seconds. It is helpful for monitoring and making decisions while a robot performs surgery.[9]
- Accurate decision: AI system collects background information about the patient’s disease. With the assistance of past medical history, it makes an accurate decision of the treatment.
- Teaching and learning: AI system is the best technology to automate necessary activities in education. Dentistry students can learn the best methods of treatment of complex cases. AI provides the best way to

point out the mistakes and improves the working of dentistry students. In the longer term, AI can improve the teaching and learning process and may change the role of an educator.[3]

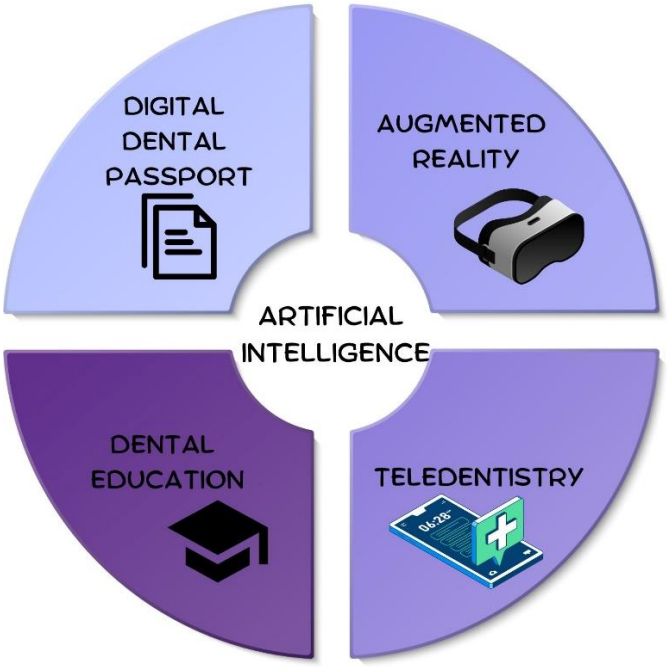

Fig 2: Schematic representation of incorporating AI into dental curriculum

Application of Artificial Intelligence (AI) in Prosthodontics

Prosthodontics is the dental specialty about the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues by using biocompatible substitutes. AI has undoubtedly forayed into this branch with its active engagement in fabrication of removable and fixed prosthesis, preparation of finish margins, shade selection, implant prosthesis, maxillofacial prosthesis, establishment of stable maxilla-mandibular relationship, and a variety of other therapeutic plans.[8]

The integration of AI has substantially increased accuracy, precision, and dependability, thereby impacting clinical outcomes. Increasing number of practices, dental setups, and educational institutes are acquiring and getting accustomed to three-dimensional digitalized dentistry. As digital dentistry advances, the role of AI and its application will continue to grow.[10]

AI in Diagnosis and Treatment planning in Prosthodontics

A prompt and accurate diagnosis is the backbone of treatment planning. With the increasing use of three-dimensional scanning and imaging, data generation has increased significantly. AI has the distinctive ability to process this huge amount of data and extract relevant clinical information for an optimal diagnosis. This diagnostic information is useful to accurately identify problems and offer ideal treatment plans. The speed and accuracy of AI is useful for the early detection of oral diseases and conditions such as caries, periodontal disease, and oral cancer, optimization of dental workflow, efficient time management, and reduction in labour cost.[11]

According to Shajahan et al., AI aids decision support systems by combining patient data such as vital signs, medical history, health status, and drug use for accurate and exact diagnosis and treatment planning.[1] According to Pradhan et al., AI provides patients with knowledge on suitable drugs and the easiest method of treatment, as well as the proper time of medication and information about its side effects if not taken on time.[3]

AI can be used to create 3D models of the patient's mouth, which can then be used to plan treatment. This can help dentists to visualize the best way to restore the patient's teeth and bite, and to ensure that the treatment is precisely executed.[6]

AI also offers insights into the type of prosthetic rehabilitation required to formalize an individualized treatment plan. It can help in designing the prosthesis, determining its type (removable or fixed), and selecting components.[11]

AI can identify patterns and models that may be challenging for humans to discern or would require significantly longer time. AI has been able to identify periodontal compromised premolars and molars with 90% and 95% accuracy, respectively.[12] This information is extremely valuable for establishing treatment protocols, leading to a comprehensive improvement in diagnostic accuracy and overall prosthetic treatment outcomes.[13]

AI and Removable dental prosthesis

Removable partial dentures (RPD) are less invasive and cost-effective measures for providing prosthetic rehabilitation of missing teeth and associated structures without further loss of the remaining teeth.[14] Individualization of dentures according to the requirements of the patient and its design are the most important factors in the fabrication of RPD.[6] AI algorithms aid in the development of a more personalized and customized approach to RPD design, as it can analyse patient data and create a design that is unique to the individual patient's needs and anatomy. AI can be used in the fabrication process of RPDs through 3D printing technology. 3D printing technology enables the fabrication of RPDs in a more efficient, accurate, and cost-effective manner compared to traditional methods.[15]

Furthermore, AI can be used in the evaluation of RPD fit and function. Computer-aided analysis of RPD fit can provide accurate measurements and assessments of the prosthesis' fit, occlusion, and overall function. This can aid in the diagnosis and correction of any issues with the prosthesis, leading to improved patient satisfaction and outcomes.[16]

Takahashi et al. studied the use of AI to construct RPD by categorizing partially edentulous arches using a Conventional neural network (CNN) model. The CNN algorithm achieved diagnostic accuracy of 99.5% in the maxilla and 99.5% in the mandible, with a correct prediction rate of more than 95% across all dental arches.[17] AI aids in the prediction of models for denture tooth microhardness and surface roughness, as well as the prediction of facial soft-tissue distortion after complete denture prosthesis. It also aids in predicting the cosmetic reconstructive consequences in edentulous patients.[18] Vohra et al. used AI to analyse denture border extension and found that the LOGISTIC REGRESSION model-Naïve Bayes Algorithm can categorize denture base extensions based on photographs, IOPA, and OPG. It may classify and categorize dentures based on the quality of their extensions.[19]

AI and fixed dental prosthesis

The use of AI in fixed prosthodontics can help in improving the accuracy and efficiency of tooth preparation. AI algorithms can analyse and learn from a large database of successful crown designs, providing insights into the optimal contour, extension, and marginal line surrounding the teeth for each case.[2] AI is useful to design the occlusal morphology of the crown in accordance with that of the opposing teeth with better emergence profile, precise marginal fit and more accurate shade matching which enhances the aesthetics of FPD.[11] In addition, AI can assist in the tooth margin preparation process by automating the extraction of marginal lines with precision, which traditionally required advanced technical skills and time-consuming manual labour.[2] The accuracy of this AI model in identifying tooth preparation lines has been found to be 97.43%.[20]

AI and Implant Prosthodontics

In the field of oral implantology, AI can be used to: -

- Identify the best implant placement sites: AI has been used to optimize implant placement and planning by analyzing CBCT images and creating a 3D model of the patient's jawbone. This can help to identify the ideal location and angle for implant placement, which can improve the overall success rate of the procedure.[21]
- Predict implant success: AI can be used to predict the likelihood of implant success based on a variety of factors, such as the patient's medical history, the quality and quantity of the jawbone, and the type of implant used.[12] AI is useful to predict implant prognosis through analysis of osseointegration success, risk factors, and bone anatomy along with finite element analysis calculations.[22] Different AI models including regression analysis, decision tree learning, logistic regression, and classifier neural network is useful to predict implant success. AI models can also be used to identify the stress at implant-bone interface by using implant length, thread length, and thread pitch. Additionally, it is useful to compute modulus of elasticity at implant-bone interface.[11] However, the success rate of AI in predicting implant success or osseointegration has been found to vary between 62% - 80%.[12]
- Surgical guide fabrication: Digital planning software allows clinicians to create a virtual surgical guide that can be used to guide implant placement during surgery. Rapid prototyping technology can then be used to create the physical surgical guide, which can be used during surgery to ensure accurate placement of the implants.[2]
- Optimize implant design: AI can be used to optimize the design of dental implants to improve their strength, durability, and osseointegration.
- Optimize occlusal scheme designing: Even for implant supported prostheses occlusal analysing devices and AI can be used to design an occlusion which has least unwanted interferences, thus leading to better and long-term stable prostheses.[23]

In a study by Lee J et al, convolutional neural networks (CNNs) based on AI were used to categorize implants using panoramic and periapical radiography. According to the study's findings, the AI-CNN system is almost as good at categorizing implant procedures as humans are.[24]
An AI model developed by Lerner et al. aims to reduce errors in placing and cementing CAD/CAM implant prostheses, especially with monolithic zirconia crowns. It helps locate subgingival abutment margins and allows dentists to focus on tooth preparation, preserving occlusal and interproximal contacts. The study involved 90 patients with 106 implants from 2016 to 2019, showing a high survival rate of 91% and success rate of 93% for zirconia implants in posterior teeth. These results demonstrate the AI model's effectiveness in improving outcomes in dental implant procedures.[25]

AI and Maxillofacial prosthesis

AI has been making significant contributions to the field of maxillofacial prosthodontics. By using convolutional neural networks (CNNs) to mimic human neurons, AI powered prosthetic devices can help patients with maxillofacial abnormalities or injuries to restore both their function and aesthetics. For instance, AI powered prosthetic eyes can help patients see, while smart reading glasses with voice-activated technology can assist the visually challenged in reading text and identifying faces.[26]
In addition, tissue engineering has also been utilizing AI to develop skin replacements for wound regeneration. Artificial skin grafts can provide temporary wound coverings or long-term skin replacements, and their primary functions are to give oxygen, prevent dehydration, promote healing, and guard against infections.[27]
Another field where AI has shown its potential is in artificial olfaction, which has been captivating scientists for about four decades. The electronic nose model is an example of an artificial olfactory system that mimics the human olfactory detection system using a variety of electronic sensors. This technology can be used in various sectors, such as disease diagnosis, environmental monitoring, public safety issues, the food industry, and agricultural production.[28]

AI and Computer Aided Designing and Computer Assisted Manufacturing (CAD/CAM)

Prosthodontics relies on CAD/CAM systems and three-dimensional digital workflows to create precise removable and fixed prostheses. Intra-oral scans initiate the process, with CAD/CAM software designing and fabricating the prosthesis through printing or milling. This technology is instrumental in making inlays, onlays, crowns, and bridges efficiently, saving time, resources, and reducing human errors in the final prosthesis.[11]
AI integrated with CAD/CAM enhances prosthetic rehabilitation by automating the detection and labelling of crown preparation margins. It processes extensive data to create aesthetically pleasing prostheses based on factors like facial proportions and patient expectations.[11] AI also shapes crown morphology to match opposing teeth.[29]
For crown cementation, AI models reduce errors by detecting subgingival abutment margins, allowing dentists to focus on tooth preparation and maintaining contacts. CAD/CAM uses additive manufacturing or subtractive milling to produce prostheses, and the AI-CAD/CAM synergy improves precision, reduces unnecessary lab work, and shortens delivery times.[30]

Challenges with AI and its future scope

Some of the challenges that need to be addressed before AI can be fully implemented in the field of Prosthodontics:
Data collection and labelling: The development of AI-powered tools requires large amounts of data, which must be carefully labelled to train the algorithms. This can be a time-consuming and expensive process.
Computer power: AI algorithms can be computationally demanding, which requires powerful computers. This can limit the accessibility of AI-powered tools to some practitioners.
Ethical considerations: The use of AI in healthcare raises a number of ethical considerations, such as patient privacy and the potential for bias in the algorithms. These issues require careful considerations, before AI can be incorporated in the field of prosthodontics and dental implants.
Despite these challenges, the future of AI in prosthodontics and dental implants is bright. As AI technology continues to develop, it is likely that AI will play an increasingly important role in these fields, improving the quality of care that dentists can provide to their patients.[23]

Conclusion

The future of AI in prosthodontics and dental implants looks promising. AI-driven tools have the potential to transform procedures and enhance the quality of care offered by dentists. As AI technology advances, we anticipate further innovative and beneficial applications in this field, promising continued improvements in patient outcomes.

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