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ARTIFICIAL INTELLIGENCE IN PROSTHODONTICS- A REVIEW

Authors:

Dr. Nazish Baig[1], Dr. Sakshi Bhatkar[2], Dr. Babita Yeshwante[3], Dr. Isha Gotmare[4], Dr. Kanchan Mokashi [5]

1) MDS, Professor and PG Guide, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
2) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
3) MDS, Professor and Head of the Department, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
4) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
5) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.

ABSTRACT:

Objective- The purpose of the article is to present a narrative review of the literature related to the applications of artificial intelligence in the field of prosthodontics.

Materials and methods- A literature search was performed in the online databases – PubMed, Science Direct, Medline and Google Scholar with the following keywords – artificial intelligence, prosthodontics, dentistry.

Artificial intelligence is capturing global interest due to its significant advancements in intelligence innovation. Its applicability spans across various fields, from automation to dentistry. Particularly in Prosthodontics, AI plays a vital role by assisting in prosthesis design and the creation of functional maxillofacial appliances, serving as a boon for dental practitioners. Moreover, it aids in patient documentation, diagnosis, treatment planning, and patient management, enabling dental professionals to enhance efficiency and effectiveness in their work.

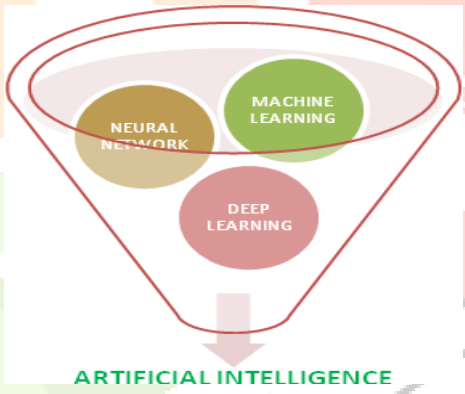
INTRODUCTION:

The concept of working smarter, not harder, resonates deeply with every individual. Granting machine the ability to think and act like humans could revolutionize numerous fields, reducing the reliance on manpower. Dentistry, with its complexities, particularly stands to benefit from such advancements. Artificial intelligence has the potential to alleviate the stress and manpower demands in dental healthcare, offering precise and comprehensive treatment as expectations for quality care rise with age. Artificial intelligence provides sophisticated decision-support tools, a term coined by John McCarthy in 1955. It refers to machines' capacity to mimic human knowledge and behavior.[1]

Prosthodontics, the branch of dentistry concerned with oral structure diagnosis, treatment planning, and rehabilitation, can greatly benefit from AI. This field focuses on various aspects, including removable and fixed dental prosthesis fabrication, implant procedures, and maxillofacial prosthesis construction. AI integration can significantly enhance treatment protocols in prosthodontics.[2]

Artificial intelligence is commonly classified into three types: artificial narrow intelligence (ANI), artificial general intelligence (AGI), and artificial superintelligence (ASI). ANI, also known as weak AI, exhibits specific abilities tailored for particular tasks.

KEY ASPECTS OF AI



Machine learning empowers computers to deduce their own rules through sophisticated algorithms. It finds applications across various industries such as e-commerce, automotive, internet search, sensors, robotics, speech recognition, and image recognition.

Machine learning is categorized into four main types:

- Supervised learning: Computers utilize labelled training data provided by human experts.
- Unsupervised learning: Computers analyse data without predefined labels, often clustering or grouping the data autonomously.
- Semi-supervised learning: This approach combines a large amount of unlabelled data with a smaller set of labelled data to enhance learning accuracy.
- Reinforcement learning: Computers engage in sequential experimentation to achieve goals while interacting with dynamic environments.[3]

Neural networks, mimicking the structure of the human brain, utilize artificial neurons to execute algorithms. Deep learning, a subset of machine learning, employs computational layers to process input data. Sometimes referred to as convolutional neural networks, deep learning networks offer advanced analytical capabilities.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE

Decision Support Systems

Healthcare systems generate vast amounts of data, providing optimal learning inputs for machine learning-enabled decision support systems. Clinical decision support enhances diagnostic accuracy and assists healthcare professionals in navigating clinical complexities. Its applications extend to various dental specialties such as prosthodontics, orthodontics, periodontics, and oral surgery, aiding in condition analysis and treatment planning.

Moreover, it plays a crucial role in minimizing erroneous claims within dental insurance by verifying patient-provided details for accuracy. Looking ahead, dental clinics may adopt comprehensive AI care systems, potentially replacing traditional dental assistants. These systems could utilize patient analysers to formulate treatment plans based on factors like age, gender, vital signs, medical history, health conditions, and medication usage before each appointment.[3]

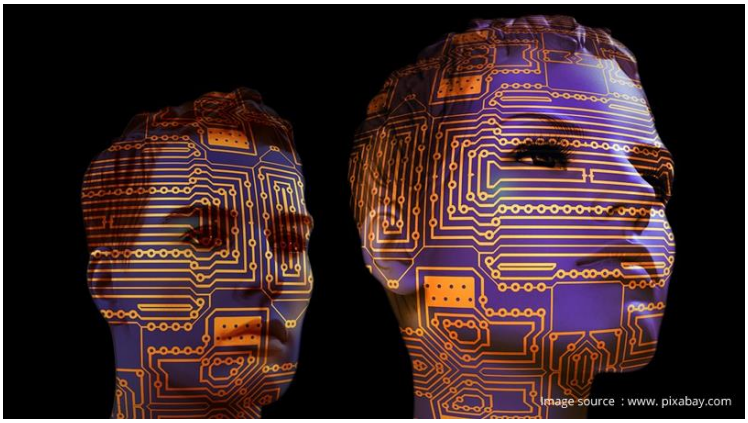
CAD/CAM and AI

In Prosthodontics, both patients and clinicians hold high expectations for the quality of prostheses. Despite the considerable manpower and machinery involved in achieving optimal outcomes, human effort alone may occasionally fall short of meeting these expectations. To streamline processes and conserve time and energy, computer-aided design and manufacturing units have been developed, allowing for customized designs to be milled or printed based on patient preferences.

One significant advantage of AI is its ability to analyse and learn from vast datasets, including millions of doctor-approved crowns stored in databases, with new cases regularly added to the cloud.[1] Aesthetic considerations often involve the evaluation of extensive dental anatomy information. However, when conventional CAD-CAM systems are used for implant prosthesis cementation, various issues such as positional errors, cementation errors, and occlusal or interproximal adjustments with abutments may arise.

To address these challenges, Henriette Lerner et al. proposed an AI model aimed at minimizing errors in the fabrication of fixed implant prostheses using monolithic zirconia crowns. This AI model assists in detecting subgingival margins of abutments and enhances dentist focus on tooth preparation and maintaining interproximal and occlusal contacts, thus reducing errors and time consumption.

The study, conducted from 2016 to 2019, included 90 patients with zirconia implant prostheses in posterior teeth, with a gender distribution of 7 males to 11 females. A total of 106 implants were analysed, with training data for the AI model comprising intraoral scans, radiographs, photographs, and CAD images. Promising results were observed, with a 91% survival rate and a 93% success rate for zirconia implants in posterior teeth fabricated using the AI model. These outcomes underscore the proficiency of the AI model and support its integration into the field of Prosthodontics.[2]



Implant Therapy and AI

The emergence of implantology has addressed several limitations associated with fixed and removable prostheses. Implants offer increased resistance to dental diseases, help preserve residual ridges, and provide enhanced support, especially in distal extension cases. Widely utilized in dentistry for replacing missing teeth or full mouth rehabilitation, implants have seen growing acceptance in recent years, attributed to their improved aesthetics and stability. With approximately 4000 dental implant varieties available worldwide, it's crucial for dentists to accurately recognize and classify them to prevent the need for replantation or repair due to mechanical or biological complications. Common methods for implant classification include CAD-CAM and panoramic radiographs.[2]

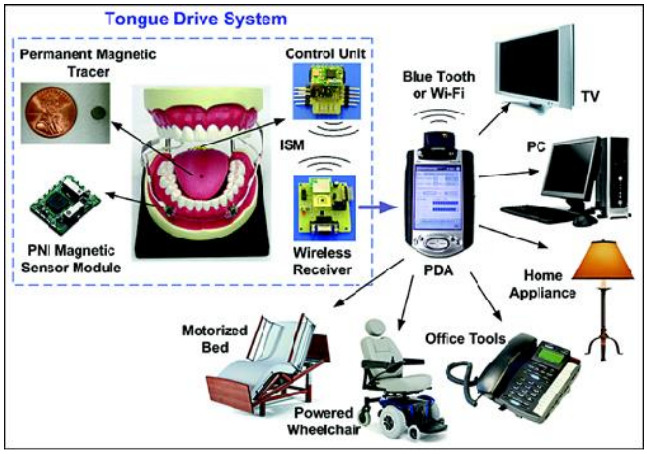
The success of dental implant treatment planning can be greatly enhanced by combining CBCT images with intraoral scans. The integration of AI into implantology holds the promise of merging these modalities and shaping the future of prosthesis design.[3]

Researchers at the Finnish Centre for Artificial Intelligence (FCAI), the University Hospital of Tampere, Planmeca, and the Alan Turing Institute have proposed a new model to precisely and automatically identify the position of the mandibular canal for dental implant procedures. Utilizing object detection based on deep learning, implant systems can be identified from panoramic radiographic images.[5]

Yomi stands out as the first reported surgical robot in dentistry. Developed by Neocis, Inc., it is a fully assisted dental implant robot that received approval from the U.S. Food and Drug Administration in 2017.[5]

Tongue Controlled Devices

The Tongue Drive System (TDS) represents a wireless and wearable assistive technology created to empower individuals facing severe motor impairments like tetraplegia to interact with their surroundings through voluntary tongue movements.[6] This innovative system analyzes tongue motions within the oral cavity and executes predefined commands accordingly. These commands prove instrumental in tasks such as accessing a computer, maneuvering a wheelchair, or managing the user's environment[3]



Maxillofacial Prostheses and AI

In the United States, the development of the bionic eye has reached a significant milestone, undergoing testing in a dozen patients with vision impairments. These remarkable devices offer individuals the opportunity to regain vision through the assistance of artificial intelligence, without the need for surgical intervention. Equipped with a smart camera mounted on specialized glasses, users can read text and recognize faces. The captured information is processed by a small headset, converting it into audio feedback relayed to the ears of visually impaired individuals.

In addressing the loss of sensory capacity resulting from limb amputation, the California Institute of Technology (USA) and the Federal Polytechnic School of Zurich (Switzerland) are pioneering the development of artificial skin. Comprised of a thin, transparent film of pectin and water, this innovative tissue detects temperature variations within the range of 5 to 50 degrees Celsius.

Artificial olfaction, crucial in robotics, replicates the human olfactory system's ability to identify various smells. This technology finds applications across diverse fields including environmental monitoring, disease diagnosis, public security, agricultural production, and the food industry.[3]

Dentures and AI

The classification of dental arches serves to maintain standardized outcomes, facilitating proper design and description of edentulous spaces within the arch. This classification also enhances communication between dentists, ensures intra-operator consistency, and simplifies treatment planning. Currently, Kennedy's classification is predominantly used for this purpose.

In a methodological study conducted by Takahashi, an AI model was developed using Convolutional Neural Networks (CNN) to classify dental arches, aiding in denture fabrication. The study utilized oral photographic

images, totalling 1184, including 748 of the maxillary arches and 438 of the mandibular arches. Arch types encompassed complete edentulous, arches with posterior tooth loss, bounded edentulous space, and intact arches. The dataset was split into a training set comprising 1016 images (85%) and a testing set comprising 168 images (15%). TensorFlow and Keras were employed for CNN model development.[2]

Through autonomous learning procedures, the computer classified the training dataset based on learning and subsequently predicted dental arches. The Percentage of Correct Prediction (PCP) was recorded, with median PCP results indicating high accuracy across arch types. For the maxillary arch, PCP ranged from 97.5% to 100%, and for the mandibular arch, it ranged from 98.8% to 100%. The model's learning performance was evaluated using the Area Under the Curve (AUC), which demonstrated high diagnostic accuracy (AUC = 0.98). Additionally, diagnostic accuracy values were notably high for both the maxilla (99.5%) and mandible (97.5%).[7]

These findings suggest the potential for AI models to assist clinicians in accurately classifying dental arches, thereby facilitating the design of high-quality Removable Partial Dentures (RPD) tailored to each patient's needs.

Limitations and future scope:

AI relies heavily on datasets, which need to be accurately classified and filtered to ensure optimal model training. However, limitations arise when datasets are primarily in paper format, and data consolidation is hindered by a lack of awareness regarding follow-up treatments. Although the medical sector has begun digitizing diagnoses and reports, there is still a considerable journey ahead to achieve accurate data suitable for model training.[2]

Looking to the future, the implementation of AI presents exciting opportunities, particularly in decentralizing the treatment process. AI enables medical professionals to conduct remote treatments more effectively, offering improved accuracy in disease diagnosis. In the future, AI predictions can be integrated with human diagnosis, enhancing the likelihood of accurate diagnostics and leading to more effective treatment outcomes

Conclusion:

Every study consistently demonstrates higher accuracy in prediction results compared to human counterparts. Researchers are capitalizing on this advantage to harness AI for improving oral and overall health outcomes. The future of dentistry holds great anticipation for the development of these technologies, as AI is poised to play a significant role.

AI possesses disruptive potential to revolutionize processes across all fields of dentistry. However, despite its promise, the adoption of AI in prosthodontics remains somewhat hesitant, largely due to the complexity of prosthetic treatment concepts. Nevertheless, AI systems excel in processing and analysing large datasets to classify outcomes and streamline repetitive workflows. They provide valuable support in evidence-based decision-making, especially for less experienced practitioners, and aid in analysing individual patient cases to ensure more standardized yet personalized treatment protocols.

The integration of AI technologies in prosthodontics opens up a wealth of innovative possibilities, including AI systems for designing occlusal surfaces for crowns, generating automatic setups for complete dentures, determining emergence profiles in implantology, and designing frameworks for removable partial dentures. AI also holds potential in various aspects of denture fixture classification, marginal line extraction, and minimizing human errors in implant cementation. Additionally, as an educational tool, AI offers valuable support for undergraduate students in their professional development.

While there are virtually no limitations to leveraging the power of AI in prosthodontics, financial considerations often dictate the development and widespread implementation of new AI technologies, favoring economically profitable areas. Nonetheless, the future holds great promise for further advancements and research in AI, paving the way for exciting developments in dentistry.

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