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Artificial Intelligence: Basics and Recent Health Care Protocols in Dentistry

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Abstract - Artificial Intelligence (AI) has revolutionized healthcare and dentistry by enabling accurate diagnosis, prediction, and personalized treatment. This review article provides an in-depth understanding of AI in healthcare and its impact on dentistry. AI technology has transformed various aspects of dental practice, including diagnosis, treatment, and patient care. AI-powered image processing systems have significantly assisted dental professionals in diagnosing and treating dental diseases. Additionally, AI technology has improved patient management and communication, enabling personalized care and enhancing the overall dental experience.

In dentistry, AI has been applied in various areas, including restorative dentistry, endodontics, and regenerative dentistry. AI models have shown accuracy in detecting dental caries, vertical root fractures, and periapical lesions. In endodontics, AI has displayed accuracy in diagnostic and prognostic evaluations, enhancing treatment planning and success rates. Despite the benefits, AI technology faces challenges, including the need for large datasets, complex mechanisms, and high costs. However, the future of AI in healthcare and dentistry looks promising, with potential applications in precision and accuracy, research exploration, and repetitive task management.

Recent advances in AI have opened up new possibilities, including deep learning models and integration with other technologies. As AI continues to evolve, it is expected to drive innovation, improve efficiency, and enhance human life. Further research is needed to test the dependability, relevance, and expenditure of AI models before integrating them into routine clinical work. Nevertheless, AI has the potential to transform dentistry, improving diagnostic accuracy, reducing costs, and enhancing patient outcomes.

***Key Words*:** Artificial Intelligence, Machine learning, Deep learning, Neural networks, Artificial Intelligence in healthcare, AI in restorative dentistry, AI in Endodontics, AI in regenerative endodontics

1. INTRODUCTION

The advent of Artificial Intelligence has revolutionized various industries and healthcare is no exception.[1] AI has transformed the healthcare industry by enabling streamlined and accurate diagnosis, prediction of disease, and customization of treatments.[2] AI technology has also significantly impacted the field of dentistry.[3] Dental professionals have been utilizing this technology in various aspects such as diagnosis, treatment, and patient care.[4] The objective of this review article is to provide an in-depth understanding of Artificial Intelligence in healthcare and its effect on dentistry.

2. Basics of Artificial Intelligence

Artificial Intelligence: Artificial intelligence originated in 1950's. [5] AI represents simulated images in

machines. AI is a subset of Data science. [6] Aims to build machine capable to think like humans. [7] AI, also known as Machine Intelligence, functions like machines. It adheres to the fundamental machine hierarchy of Input, Processing, and Output. The atomic structure representation of artificial intelligence shows machine learning, deep learning, neural networks, working models, different languages and various applicability (Fig-1). In dentistry, the input data might be voice data (sounds of hand piece), text data (medical or treatment records, experimental parameters), or picture data (spectral or radiographic images, photos). The result might be a prognosis, diagnosis, treatment, or disease prediction. It can interpret clinical cues, do cephalometric analysis, or recognize lesions based on voxel differences to arrive at a diagnosis. Models: AI models operate in two phases: "training" in the first phase and "testing" in the second. The parameters of the model set are determined by the training data

Machine learning: Machine learning are methods used to predict results out of a data set. Making it easier for machines to acquire data already available and resolve problems without human intervention. Originated in 1960's. ML is the practice of getting machines to make decisions without being programmed. ML is a subset of AI and Data science. Makes machines to learn through data.

Deep learning: It has numerous computational layers that create a network of neurons that identifies patterns on its own thereby improving detection. Originated in 1970's. Uses neural networks to solve complex problems. DL is a subset of ML, AI and Data Science. Builds networks to automatically identify patterns for future detections

Data science: a process of analysis of data and extraction of information from the analyzed data. Big data analyses a huge amount of data that is steadily expanding in the right direction over years to give consumers correct information.

Three-dimensional (3D) Imaging: Three-dimensional (3D) imaging in artificial intelligence (AI) enables the creation and analysis of complex spatial data, revolutionizing various applications. AI-powered 3D imaging systems can reconstruct and interpret 3D scenes from 2D images or sensor data, allowing for accurate object recognition, tracking, and manipulation. Techniques like stereo vision, structured light scanning, and Lidar sensing enable AI models to perceive depth and spatial relationships. These capabilities are crucial in fields like robotics, autonomous vehicles, and healthcare, where AI can use 3D imaging to navigate environments, detect obstacles, and analyze medical scans. Additionally, 3D imaging facilitates the development of immersive technologies like augmented reality (AR) and virtual reality (VR), which rely on AI to generate and interact with 3D environments. By leveraging 3D imaging, AI systems can better understand and interact with the physical world, enabling applications like precise object manipulation, facial recognition, and gesture analysis. As AI continues to advance, the integration of 3D imaging will play a vital role in enhancing the accuracy and effectiveness of AI-driven solutions, driving innovation and transforming industries. This technology has vast potential for growth and development.

Neural networks: use artificial neurons and compute signals which execute similarly to that of the human brain.

1. **ANN: Artificial Neural Network**

   Whenever there is an Input it is activated. There are multiple hidden layers as in Deep learning model. It is a Feed-Forward neural network. It is interpretable. Stores information on the entire network. Ability to work with incomplete

knowledge. Offers fault tolerance and have distributed memory (Fig-2).

2. **CNN: Convolutional Neural Network**
   Convolusional neural network. Multiple convolutions and Max-pooling occurs with ReLU activation. (Fig-3). Gets an entirely connected or pooled output through non-linear processing. Very high accuracy in image recognition problems. Capability of automatic detection of important features. Weight sharing is an advantage with this type of neural network (Fig-4).

3. **RNN: Recurrent Neural Network**
   It learns to predict an outcome of a layer. It is known as a Memory Cell. System self-learns and continues working towards a correct prediction during back-propogation (Fig-5). Remembers each and every information through time. Can be used with convolutional layers in image recognition. Has a Long Short-term Memory (Fig-6).

Computer languages: Artificial intelligence (AI) leverages a variety of computer languages to develop intelligent systems that can learn, reason, and interact with humans. Python is a dominant force in AI development due to its simplicity, flexibility, and extensive libraries such as TensorFlow, PyTorch, and scikit-learn, which facilitate tasks like machine learning and deep learning. R is another popular language, particularly for statistical analysis and data visualization, making it a favorite among data scientists for tasks like predictive modeling and data mining.

Java and C++ are also widely used in AI applications, especially those requiring robustness, scalability, and integration with existing systems. Java's versatility and platform independence make it suitable for large-scale AI projects, while C++'s performance and control over system resources are invaluable for applications like computer vision and robotics.

Emerging languages like Julia are gaining traction in the AI community due to their high-performance capabilities, dynamism, and ease of use. Julia's ability to approach the performance of C++ while maintaining the simplicity of Python makes it an attractive choice for complex AI computations.

The choice of language often depends on the specific requirements of the AI application, such as natural language processing, computer vision, or predictive analytics. Each language has its strengths and weaknesses, and understanding these differences enables developers to select the most appropriate tool for their AI projects, ultimately leading to more efficient and effective solutions. This diversity in language options empowers developers to craft tailored solutions that meet the unique demands of their AI applications.

Transcriptions: Transcription in artificial intelligence (AI) involves converting spoken language into text using automatic speech recognition (ASR) technology. AI-powered transcription systems can process audio or video recordings and generate accurate transcripts in real-time or post-processing. These systems leverage machine learning algorithms and natural language processing (NLP) to recognize patterns in speech, including nuances like accents, dialects, and context-specific terminology. Transcription applications are diverse, ranging from generating subtitles for videos, creating meeting notes, and transcribing interviews to aiding individuals with hearing impairments. The accuracy and efficiency of AI-driven transcription have significantly improved, making it a valuable tool in various industries, including media, healthcare, education, and law. By automating the transcription process, AI saves time, reduces manual effort, and

enhances the accessibility and searchability of audio and video content, thereby increasing productivity and facilitating information retrieval. This technology continues to evolve.

Working Model: Artificial intelligence (AI) working models are computational frameworks that enable machines to perform tasks that typically require human intelligence. These models are trained on large datasets, allowing them to learn patterns, relationships, and decision-making processes. Some prominent AI working models include machine learning (ML) models, which can be further categorized into supervised, unsupervised, and reinforcement learning models. Deep learning models, a subset of ML, utilize neural networks with multiple layers to analyze complex data such as images, speech, and text. Other notable models include decision trees, random forests, and support vector machines. These models are applied in various domains, including natural language processing, computer vision, predictive analytics, and robotics. By leveraging these working models, AI systems can accomplish tasks like image recognition, sentiment analysis, predictive forecasting, and autonomous navigation. The choice of model depends on the specific problem, data characteristics, and desired outcome. As AI continues to evolve, new and hybrid models are being developed to tackle increasingly complex challenges and improve performance. This enables AI systems to drive innovation and efficiency.

Artificial Intelligence in healthcare:

Artificial Intelligence has provided a solution to many of the challenges faced in the healthcare industry. One of the biggest applications of AI is in the development of smart clinical decision support systems. These systems enable healthcare providers to access accurate and relevant information in real-time and can be used in the diagnosis of various diseases. Additionally, AI algorithms can be trained to analyze extensive health records, detect patterns, and create predictive models that allow for the early detection of illness.

One of the most significant applications of AI is in the development of image recognition systems. Medical imaging plays a vital role in the diagnosis and treatment of diseases such as cancer, cardiovascular disease, and neurological disorders. AI-powered image recognition systems can help radiologists quickly and accurately diagnose illnesses by analyzing images and identifying abnormalities that may be difficult to detect by the human eye.

TYPES OF AI IN HEALTHCARE SECTOR

- **VIRTUAL**

A. Electronic Health Records
B. Drug Interactions
C. Scheduling Appointments
D. Drug Dosage Algorithm
E. Diagnosis & Prognosis
F. Imaging

- **PHYSICAL**

A. Robotics for surgery
B. Robotics for elderly care
C. Tele-presence
D. Rehabilitation

Artificial Intelligence in Dentistry:

The development of AI technology has led to significant advancements in the field of dentistry.[8] AI technology has transformed various aspects of dental practice, including diagnosis, treatment, and patient care.[9] One of the most significant contributions of AI in dentistry is in the field of image processing.[10] AI-powered image processing technologies enable dental professionals to streamline the diagnosis process by analyzing X-rays, CT scans, and other digital dental images.[11] These systems can also identify hard-to-detect abnormalities in

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the teeth and gums, leading to early detection and treatment of dental diseases. AI models are also continually evolving to help accelerate root canal therapy by automating aspects of canal shaping and cleaning procedures.

Another significant field to AI application in dentistry is patient management and communication. AI-powered chat-bots offer patients a real-time and interactive experience, answering their queries promptly and directing them to a patient portal where they can make appointments, pay their bills, or even get virtual consultations from a dentist. Another exciting area that AI technology is used to monitor patients' consumption of sugar as a vital factor that contributes to dental caries and gum diseases. AI algorithms can track and identify patients' food choices and generate a healthy diet plan to aid them in healthy eating choices.

Diagnosis:

The application of artificial intelligence in the diagnosis and treatment of oral cavity diseases, as well as in the detection and classification of suspiciously changed mucosa experiencing premalignant and malignant alterations can be beneficial. [12] Even little changes at the single-pixel level that the human eye could miss are picked up. [13]

A useful tool for determining dental prognosis in light of the treatment strategy is an AI-based machine learning system. To determine a tooth's prognosis for long-term oral health and function, a thorough treatment strategy must be carefully reviewed.

Artificial Intelligence in Restorative Dentistry

A CNN based AI system, trained on a semantic segmentation method, was found to generate an area of 83.6% and 85.6% under the receiver-operating characteristic (ROC) curve for occlusal and proximal lesions respectively, signifying an excellent discriminating ability between the presence or absence of carious lesions.[14] Cone beam computed tomography (CBCT) imaging and radiographs assist in identifying a Vertical Root Fracture which perhaps is challenging to diagnose.[15] According to the study by CNN, it may be a useful tool for identifying VRFs on panoramic radiographs. In a different research, peri-apical radiographs and CBCT images were used to create a neural network to identify VRFs in teeth that were both intact and root-filled.

In comparison to pictures from 2-D radiographs, they found that fracture identification of roots on CBCT images is superior in relation to specificity, accuracy and sensitivity. Despite a tiny sample size, steerable wavelets were successfully used to detect fractures in high-resolution CBCT images. IOPA and OPG are the two 2-dimensional diagnostic methods that are most frequently employed in everyday clinical practice to detect apical periodontitis. The characteristics of peri-apical radiolucency and alveolar bone resorption can both aid in the creation of Artificial Intelligence models for the detection of peri-apical pathology and periodontitis. Lee et al., based on the level of alveolar bone loss, developed a model formulated on a deep learning network of neurons to identify periodontally challenged molars and premolars and predict hopeless molars and premolars. According to Endres et al., a deep learning algorithm model can detect periapical radiolucencies on panoramic radiographs as accurately as 24 oral and maxillofacial surgeons. As found by Orhan et al., 142 out of 153 periapical lesions could be detected by the AI system, and this detection accuracy rate was 92.8%.

Artificial Intelligence in Endodontics

In endodontics, artificial intelligence is gaining more relevance. [16] Its significance in endodontic treatment

planning and disease diagnosis is growing at the moment. [17] Even trivial to minuscule changes at the level of a single pixel that the human eye could miss can be found using AI-based networks.

Correct determination of WL is crucial for successful root canal treatment outcomes. [18] One method used to assess working length is radiography. [19] Other methods include digital tactile sense, electronic apex locators, the reaction of the patient to a paper point or file point placed into the root canal system, and CBCT imaging. Consequently, it becomes necessary to use computer-based techniques to provide consistently precise working lengths. Saghiri et al; used a model of a human cadaver to replicate a clinical setting and examined the accuracy of WL assessment by an artificial neural network. When comparing an artificial neural network with the real measurement after extraction, they discovered no change in the root length measurements. Additionally, they noted that when utilizing periapical radiographs to determine minor anatomic constriction, the ANN (96%) outperformed an endodontist (76%) by a wide margin.

Understanding the different types of root and root canal systems is a crucial element in the effectiveness of nonsurgical root canal therapy. Cone-beam computed tomography imaging and peri-apical radiography have often been employed for this purpose. Although conventional radiography is widely applied and still has an essential role in the diagnosis and treatment planning for root canal pathologies. CBCT provides high-quality three-dimensional images, thereby overcoming the limitations of conventional radiographs such as distortion and superimposition of bony and dental structures. Cone beam computed tomography imaging has shown to be more accurate in determining the root and root canal geometries. However, it cannot be advised in standard clinical practice due to radiation problems. The diagnostic performance of a deep learning system applied to panoramic radiographs for assessing the number of the distal roots of mandibular first molars, using CBCT classification as a gold standard. One of the system's strongest aspects is its ability to correctly forecast how the retreatment would turn out. The restriction was that the precision of the system could only match the information in the data.

Regenerative Dentistry

By assessing the stem cells' survival following treatment with lipopolysaccharides of bacteria in a model clinical situation, this approach was able to predict the result. [20] When the predictive ability of stem-cell viability under different bacterial lipopolysaccharide concentrations was studied using a neuro-fuzzy system (a form of ANN), a determination coefficient of 0.81 was obtained which shows that 81% of the predictive ability can be accounted for the DL system. To predict cell survival after a variety of regeneration procedures that are subject to microbial infection, the neuro-fuzzy inference system was implied as a tool. The scientists tested the viability of the cells after administering lipopolysaccharide to pulp stem cells to elicit an inflammatory response.

Current pros and cons of Artificial Intelligence

Predictive models which are based on data-driven. [21] AI can be used to diagnose patients vulnerable to tooth structure loss and root caries. [22] A recently published study utilized ANN to predict the level of case difficulty and reported a sensitivity of 94.96% by the ML algorithm. A colossal amount of data is required for precise training, which limits its potential to diagnose rare conditions such as periapical lesions other than the endodontic origin. [23] Additionally, healthcare data is not accessible and available readily due to ethical concerns such as maintenance of patients' privacy, thus rendering

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only a smaller amount of data patterns for the networks to "learn". Also, the available data often contains missing information and is also prone to selection bias which leads to the over-representation of a specific data pattern.

The technology involves complex mechanisms and often it remains uncertain how the datasets are designated, curated, and handled and may persist un-validated and insufficiently replicable to dental applications. Affordability is also a roadblock to adopting this technology in daily clinical practice as the installation of the machine incurs huge costs. Besides, the software programs also require frequent up-gradation to adapt to the changing needs.

Future of Artificial Intelligence in Health Care

- Precision and Accuracy. [24]
- Exploration for research possibilities. [25]
- Manage records. [26]
- Can do repetitive and time consuming tasks. [27]
- Robotic pets, Robotic radiosurgery.
- Function without stopping, Risk reduction.
- Diagnosis and Treatment.

CONS

- Cost incurred in the maintenance and repair.
- Lack the human touch.
- Lacks a creative mind.
- Ability of humans may diminish.
- Robots superseding humans.
- Humans may become dependent on machines.
- Wrong hands can cause destruction.

Machine learning and computer vision systems have incredible potential for future dental care, from improving early detection of oral cancer to boosting efficiency in orthodontics. As we've seen, the importance of artificial intelligence for dentistry is hard to understate. [24] When working in tandem with human dental practitioners, AI technologies improve diagnostic accuracy, reduce costs and improve long-term patient outcomes. Another major benefit is AI's ability to standardize dental diagnosis and treatment. Dentists' evaluation of patient data is subjective, and research has shown that diagnosis is not always consistent between practitioners. [25] Smart, new technologies in dentistry provide a way to significantly increase consistency, and as a result, improve patient health. In other words, AI and ML are poised to create a major win for patients and dentists alike.

Recent advances and Possibilities

Recent advances in artificial intelligence (AI) have been transformative, opening up new possibilities across various domains. One significant development is the rise of deep learning models, which have achieved remarkable success in tasks like image and speech recognition, natural language processing, and game playing. The integration of AI with other technologies, such as the Internet of Things (IoT) and block chain, has also expanded its potential applications. [26] For instance, AI-powered IoT devices can analyze data from sensors and make decisions in real-time, while block chain-based AI systems can ensure secure and transparent data sharing.

The possibilities of AI are vast and varied. In healthcare, AI can help diagnose diseases more accurately and quickly, personalize treatment plans, and streamline clinical workflows. In education, AI-powered adaptive learning systems can tailor instruction to individual students' needs, abilities, and learning styles. AI can also revolutionize industries like transportation, finance, and customer service, enabling businesses to automate tasks, predict trends, and provide personalized experiences. [27]

Moreover, the development of explainable AI (XAI) and transparent AI systems can increase trust and

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accountability in AI decision-making. As AI continues to evolve, we can expect to see significant breakthroughs in areas like multimodal learning, transfer learning, and human-AI collaboration. [27] The potential of AI to drive innovation, improve efficiency, and enhance human life is vast, and its impact will only continue to grow in the coming years. With responsible development and deployment, AI can help solve some of the world's most pressing challenges and create a better future for all. As researchers and developers push the boundaries of what is possible with AI, we can expect exciting new applications. AI combined with robotics will play a significant role in many fields in the near future.

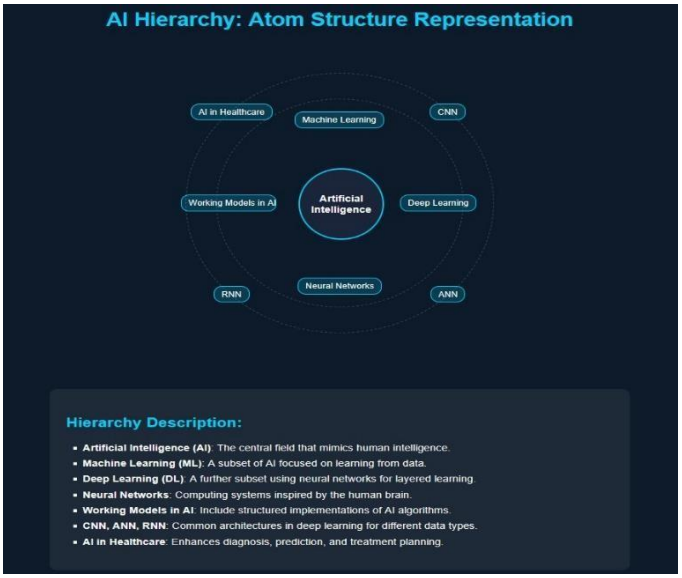

Fig - 1: Artificial Intelligence–Atom Structure Representation

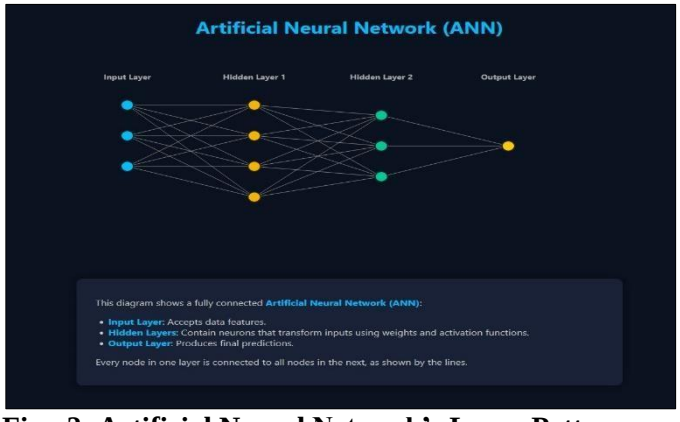

Fig - 2: Artificial Neural Network's Layer Patterns

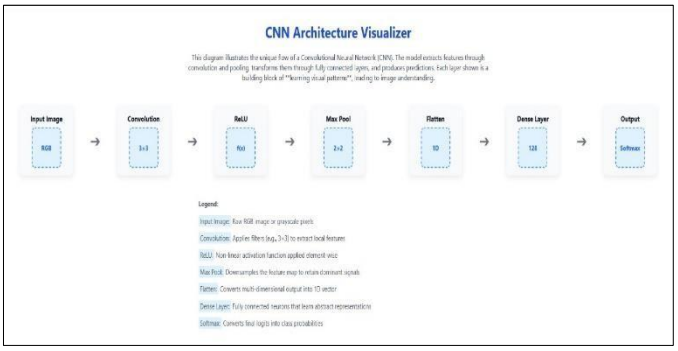

Fig - 3: Convolutional Neural Network's Architectural Visualizer

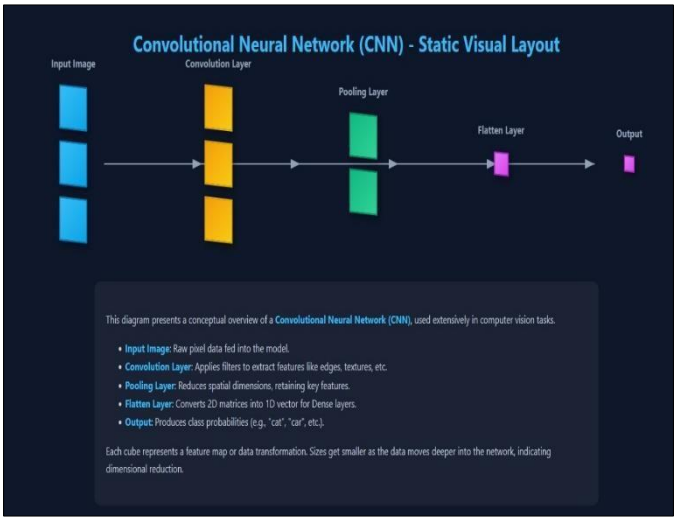

Fig - 4: Convolutional Neural Network's Static Visual Layout

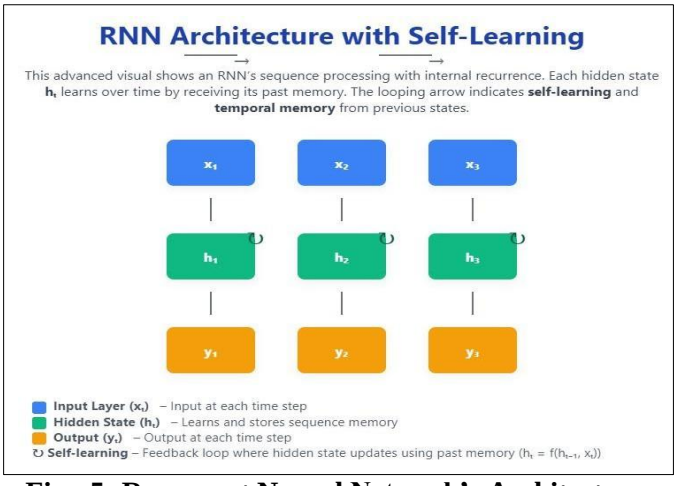

Fig - 5: Recurrent Neural Network's Architecture with Self-Learning

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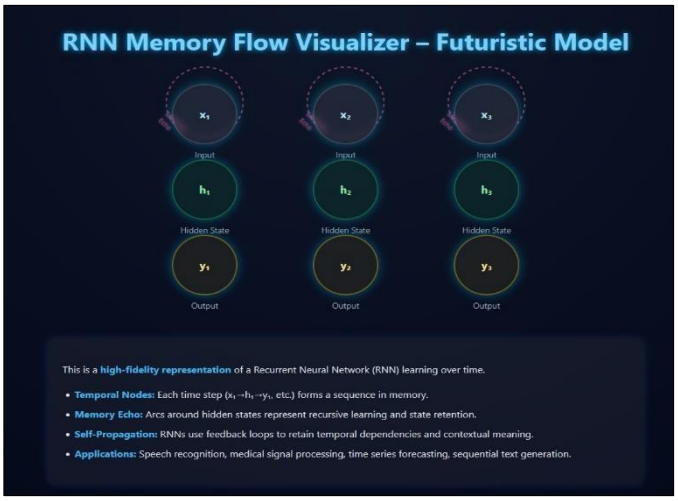

Fig - 6: Recurrent Neural Network's Memory Flow Visualizer – Futuristic Model

3. CONCLUSIONS

Artificial Intelligence has transformed the healthcare industry and revolutionized the dental industry. [28] AI-powered clinical decision support can provide accurate and real-time information to clinicians, aiding in diagnosis, treatment, and prediction of diseases. [29] In dentistry, AI-powered image processing systems have significantly assisted dental professionals in the diagnosis and treatment of dental diseases. AI technology has also provided an avenue for personalized patient care, which improves the patient's overall dental experience. With recent developments in AI technology, there is a bright future for AI in both healthcare and the dental industry. [30]

In Endodontics, AI displayed accuracy in terms of diagnostic and prognostic evaluations. The use of AI can help enhance the treatment plan, which in turn can lead to an increase in the success rate of endodontic treatment outcomes. In recent years, AI has transformed dentistry. It is rapidly progressing, with potential applications spanning various domains such as diagnosis, prognosis, and treatment prediction. The AI is used extensively in endodontics and could help in clinical applications, such as detecting root fractures, periapical pathologies, determining working length, tracing apical foramen, the morphology of root, and disease prediction. However, before integrating AI models into routine clinical work, it is still important to do additional research to test their dependability, relevance, and expenditure.

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