Management of Dental Caries in Digital Era, Artificial Intelligence perspective – Scoping Review

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Introduction

Dental Caries is defined as an irreversible microbial disease of the calcified tissue of teeth characterized by demineralization of the inorganic part and destruction of organic substance of the tooth which leads to cavitation [1]. Dental caries is the most prevalent dental disease worldwide. According to Global Burden Diseases 2017, most common health condition in permanent teeth is untreated dental caries [2]. The visual-tactile method is most commonly used technique in diagnosis of dental caries whereas in radiography bitewing radiography is most common [3]. Accuracy of early diagnosis of dental caries is still a challenging problem for dentists. Neural networks and artificial intelligence (AI) are increasingly being used in the field of dentistry. AI technology has a possibility of improving patient care through better diagnostic aids and reduced errors in daily practice [4].

Artificial intelligence is defined as the theory and development of computer systems that are able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages [5]. Convolutional Neural Network (CNN) is a tool of artificial intelligence for effective analysis of images (Figure 1) [6]. Several limitations exist in healthcare like serious diagnostic errors, mistakes in treatment, an enormous waste of resources, inefficiencies in workflow, inequities, and inadequate time between patients and clinicians [7,8]. Leaders in healthcare and computer scientists have asserted that AI might have a role in addressing all these problems [9]. It has been estimated that, per day, AI would process over 250 million images for the cost of about $1,000 [10]. Artificial intelligence will be used in augmented reality for future remote eHealth [11,12].
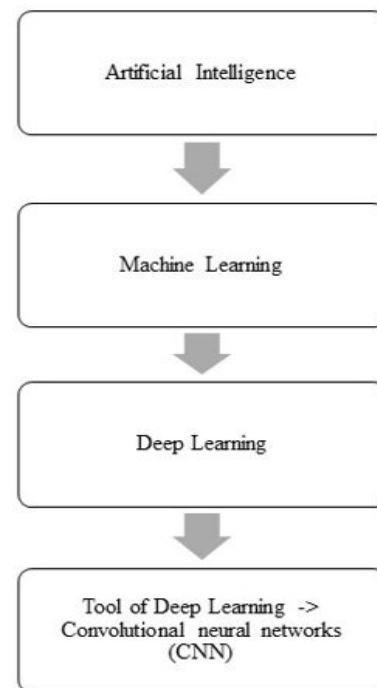

Figure 01 – Branches of Artificial Intelligence[17]

Methodology
Search Strategy

Various databases like NCBI (Pubmed), Google Scholar, Web of Science and SCOPUS were comprehensively searched for all research related to artificial intelligence integration in dental caries management from January 2000 till April 2022. The research work included in this review is according to the following inclusion criteria: 1. Full Text Articles in English language 2. Research work focusing on developing artificial intelligence network in dental caries

Table 1: *Artificial Intelligence based Dental Caries Management Software.*

S.NO	Name	Used By	Device	Functionality/ Results
1	An Artificial Intelligence–Powered Smartphone App, AICaries [13]	Children/ Parents/ Care givers	Mobile Based App	Take pictures of teeth
2	An Artificial Intelligence Model, A Multilayer Perceptron Neural Network [14]	Health Care Professionals	Multilayer Perceptron Neural Network	Considering all examiners, the diagnostic improvement using the neural network was 39.4%.
3	Support Vector Machine [15]	Health Care Professionals	Machine Learning Algorithms	accuracy of 97.1%, precision of 95.1%, sensitivity of 99.6% and specificity of 94.3% for identifying root caries
4	Convolutional Neural Networks (Cnns) For Caries Detection [16]	Health Care Professionals	Convolutional Neural Networks	The CNN was able to correctly detect caries in 92.5% of cases
5	Dentalxrai Pro [17]	Health Care Professionals	Convolutional Neural Network	Sensitivity AI device 0.81 Bitewing – 0.72 Specificity same
6	Convolutional Neural Network (U-Net) [18]	Health Care Professionals	Convolutional Neural Network	The neural network showed an accuracy of 0.80; dentists' mean accuracy was significantly lower at 0.71
7	Googlenet Inception V3 CNN Network [19]	Health Care Professionals	Deep Convolutional Neural Networks (Cnns)	The deep CNN algorithm achieved an AUC of 0.917 (95% CI 0.860–0.975) on premolar, an AUC of 0.890 (95% CI 0.819–0.961) on molar, and an AUC of 0.845 (95% CI 0.790–0.901) on both premolar and molar models
8	1. Charged-Coupled Device (CCD)Camera with Neural Network 2. Intra-Oral Digital Radiography and Neural Network [20]	Health Care Professionals	Convolutional Neural Network	Sensitivity/Specificity 1. 0.77(0.68-0.85)/0.85(0.75-0.92) 2. 0.81(0.72-0.88)/0.93(0.84-0.97) accuracy of caries depth-detection 1. 58% 2. 40%
9	ADEPT (Assistdent Enamel-Only Proximal Caries Assessment) [21]	Health Care Professionals	Artificial Intelligence (AI) Software	Caries detection – 75.8% Wrong Caries Detection – 14.6%
10	A Deep Convnet [22]	Health Care Professionals	A deep ConvNet was developed by adapting from Single Shot MultiBox Detector. The hard negative mining algorithm was applied to automatically train the model	The deep learning model is promising to detect dental caries on oral photographs captured with consumer cameras.
11	Deep Learning Based Prototype Artificial Intelligence System [23]	Health Care Professionals	Deep Learning Based Prototype System	sensitivities and specificities of the test set were 96.0% and 97.0% for caries with cavities, 95.8% and 99.0% for pit and fissure caries and 88.1% and 97.1% for approximal caries

12	CNN Model [24]	Health Care Professionals	CNN model dev eloped by 200 bitewing radiographs	The overall accuracy of the CNN model was 94.59% (94.19% for premolars, 94.97% for molars), sensitivity was 72.26% (75.51% for premolars, 68.71% for molars), specificity was 98.19% (97.43% for premolars, 98.91% for molars), PPV was 86.58% (83.61% for premolars, 90.44% for molars), and NPV was 95.64% (95.82% for premolars, 95.47% for molars)
13	Automated Machine Learning Algorithm [25]	Health Care Professionals	Parsimonious automated machine learning early childhood caries classifiers	
14	Deep Learning-Based Quantitative Analysis of Dental Caries Using Optical Coherence Tomography [26]	Health Care Professionals	A novel approach combining OCT imaging modality and deep convolutional neural network (CNN) for the detection of occlusal carious lesions	The sensitivity and specificity of distinguishing between carious and non-carious lesions were found to be 98% and 100%, respectively.
15	Deep Learning Model (Mask R-CNN) [27]	Health Care Professionals	A Deep Learning model (Mask R-CNN) can detect and classify dental caries on occlusal surfaces across the whole 7-class ICDAS (International Caries Detection and Assessment System) scale	
16	Artificial Intelligence System [28]	Health Care Professionals	An artificial intelligence system based on the deep convolutional neural network method to detect periapical pathosis on cone-beam computed tomography (CBCT) images	The AI system was able to detect 142 of a total of 153 periapical lesions. The reliability of correctly detecting a periapical lesion was 92.8%.
17	Cad System [29]	Health Care Professionals	A deep fully convolutional neural network (FCNN) consisting 100+ layers, which is trained to mark caries on bitewing radiographs.	The use of Computer Aided Diagnosis (CAD) System for clinical diagnosis provides improved performance and reliability along with avoiding problems caused by intra- and inter- examiner variations
18	Machine Learning [30]	Health Care Professionals	A deep learning model where convolutional neural network with Google Net inception v3 architecture algorithm is implemented	Proposed technique achieves 86.7% accuracy on the testing dataset.
19	Convolutional Neural Network (CNN) Algorithms [31]	Health Care Professionals	Convolutional Neural Network (CNN) algorithms in dental bitewing radiographs using VGG-16 and U-Net architecture	AI models showed superiority to assistant specialists.

20	Pyradiomics+ANN [32]	Health Care Professionals	105 statistical/morphological image features of the teeth were extracted using PyRadiomics. Artificial neural network classifier (ANN) was used firstly, to select the best features (using maximum weights) and then label the teeth: in caries and non-caries	The proposed method to predict and detect RRC using neural network and PyRadiomics features showed a reliable accuracy able to perform before starting RT to decrease the side effects on susceptible teeth.
21	A Modified Deep Learning Model [33]	Health Care Professionals	A modified deep learning model was developed using a large dataset (4,129 images) with high-quality annotations to support the automatic detection of both dental caries and periapical periodontitis.	deep learning can improve the accuracy and consistency of evaluating dental caries and periapical periodontitis on periapical radiographs.
22	CNN Classification Models [34]	Health Care Professionals	Image processing techniques and convolutional neural networks to identify approximal dental caries in bitewing radiographic images and classify them according to lesion severity.	accuracy on the test set was 73.3%,
23	Machine Learning-Based Prediction Models for Early Childhood Caries [35]	Health Care Professionals		ML-based models can show favorable performance and can be used to predict early childhood caries, identify ECC high-risk groups, and implement active preventive treatments.
24	Convolutional Neural Network (CNN) Mobilenet V2 [36]	Health Care Professionals	A convolutional neural network (CNN) was trained on a reference data set consisted of 400 cropped panoramic images in the classification of carious lesions in mandibular and maxillary third molars, based on the CNN MobileNet V2	The proposed method achieved an accuracy of 0.87, a sensitivity of 0.86, a specificity of 0.88
25	The Support Vector Machine Model [37]	Health Care Professionals	Five characteristic features of these areas were intendedly selected and calculated to be inputted into the classification stage, where five classifiers (Support Vector Machine, Random Forests, K-Nearest Neighbors, Gradient Boosted Tree, Logistic Regression) were evaluated to determine the best one among them.	the Support Vector Machine model was recorded as the best model with accuracy, sensitivity, and specificity at 88.76%, 92.31%, and 85.21%.

diagnostics and therapeutics. The keywords and MeSH terms (Medical Subject Heading) used were Dental Caries AND Artificial Intelligence", "Dental Caries Diagnosis AND artificial Intelligence", "Dental Caries AND Machine Learning", "Dental Caries Management AND Artificial Intelligence"

Results

The search yielded around 148 articles identified from electronic databases and 41 articles were identified through reference list. After removing the duplicates, the articles were screened based on eligibility criteria. Information was taken from 25 articles

Artificial Intelligence Integrated in Dental Caries Management

AI in dentistry is a growing topic, as its benefits clinicians with a high quality patient care and simplifies complicated protocols by providing a predictable outcome. Its application evolves rapidly day by day [38]. The AI softwares that have been developed in field in dentistry have focused mainly on dental disease diagnostics. Many softwares have been developed and tested in diagnosis of dental caries which will act as an adjunct to Health Care Professionals. Majority of softwares (17 out of 25) were based on Convolutional Neural Network. CNN is useful in a lot of applications, especially in image related tasks. Applications of CNN include image classification, image semantic segmentation, object detection in images, etc. [39]. The AI diagnostic softwares by Hung M et al [15] and Duong DL et al [37] were Support Vector Machine based on machine learning algorithms. The power of an SVM stems from its ability to learn data classification patterns with balanced accuracy and reproducibility [40]. An Artificial Intelligence–Powered Smartphone App, AICaries by Xiao J [13] was the only mobile based application for self-screening for dental caries by people themselves.

Limitations

Several softwares have been developed to enhance dental Caries diagnosis. The softwares are promising tools and enhance the diagnostic ability of caries detection via dental Xray, bitewing or panoramic. Only one tool was developed which was based on self-screening and dental awareness by the patient himself. All the tools have been developed and tested but none of them have been widely implemented in dental health care centres. The cost effectiveness of these tolls needs to be done before launching these tools in the market.

Recommendations and Conclusion

Dental diseases are highly prevalent in today's era. In the digital era technology can play a prominent role in dental disease diagnostics, risk factor analysis, prognosis and management. Artificial Intelligence software are helping dentists in accurate diagnosis and efficiently treating their patients. The advancements in artificial intelligence may still be in its nascent stage but in no way can replace human intelligence and skill. Artificial Intelligence can be utilized in various applications in dentistry other than enlisted in Table 1 like modified dental chair with voice assistant, dental education, teleconsultation specially in covid era, modified dental radiography, oral cancer screening by mobile based AI application precision dental prosthesis, 3D scans and aligners, AI based laboratories to design precise dental restorations, apex location or implantology for making precise surgical guides and identifying type of bone to cortical thickness etc.

Affordable dental caries AI based diagnostic tools needs to be developed and validated after which they can launched in the market. Tools should focus on engaging people by giving more importance to self-screening tools. Ai based tools should also be developed that focus on dental caries risk factor analysis and dental caries prognosis. The field of artificial intelligence has grown tremendously in the last decade. While the advances in AI like neural networking, natural language processing, image recognition, and speech recognition have transformed the field of medicine and dentistry in many ways, they have a number of drawbacks and challenges that are yet to be overcome. One of which is the high initial capital equipment costs involved [41]. The culmination of artificial intelligence along with digitization has seen a new era in the field of dentistry and its future aspects appear extremely promising.

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