A SURVEY ON MACHINE LEARNING BASED ALGORITHM FOR AUTOMATED DENTAL DISEASE DETECTION FROM EARLY CHILDHOOD TO ADOLESCENCE

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Abstract
Dental caries is a progressive, multifactorial disease that affects children and adolescents globally, often beginning as Early Childhood Caries (ECC) and extending into adolescence if left untreated. Early and accurate detection across developmental stages—ranging from primary to mixed and permanent dentition—is critical to prevent complications such as malocclusion, pain, infection, and compromised quality of life. Artificial Intelligence (AI) has emerged as a promising tool for enhancing caries detection in individuals aged 3 to 18 years, offering improvements over traditional visual and radiographic examinations. Machine learning and deep learning models, have demonstrated high accuracy in identifying early demineralization, classifying lesion severity, and analyzing radiographic and intraoral images. AI systems can also integrate multifactorial risk factors such as diet, oral hygiene practices, fluoride exposure, and genetic predisposition to provide personalized risk assessments. These technologies not only support clinical decision-making but also enable school- and community-based screening programs, thereby expanding access to preventive dental care. Despite these advancements, challenges remain in terms of data standardization, model interpretability, and ethical considerations in pediatric populations. Leveraging AI for caries detection from childhood to adolescence holds significant potential to improve early intervention, optimize resource allocation, and promote long-term oral health outcomes.
Keywords: *Dental caries; Artificial Intelligence; Pediatric dentistry; Adolescence; Machine learning; Caries detection; Preventive dentistry.*

1 Introduction

A survey on Machine learning based algorithm for Automated dental disease detection from early childhood to adolescence. Oral hygiene is one of the crucial parts during the growth of a child from the early stage of eruption of tooth. If it is neglected (pay no attention) to oral hygiene, it will cause into various dental problems from the early childhood. Specifically dental caries is one of the most common diseases that may occur due to ignorance towards oral hygiene. According to our survey from some pedodontics in India, poor oral hygiene practices can cause the dental caries and other diseases. Also, high sugar consumption, is one of the major causes of dental diseases, lack of parental awareness towards eating habits, infrequent dental checkups, use of bottle or formula milk is one of the major reasons in the growth of dental diseases.

These are the common dental conditions that are being observed in the country like India where adolescences and children are in majority. Dental caries which is most commonly observed dental condition at rate of 100% from early childhood to adolescence. Apart from this disease, dental disease, Gingivitis, Malocclusion, Fluorosis, Enamel hypoplasia, Traumatic dental injuries, Tooth eruption disorders these are the mosty common dental conditions that are observed as well. As per our survey, 20-30 cases of dental caries/week has been highly observed by pedodontics.

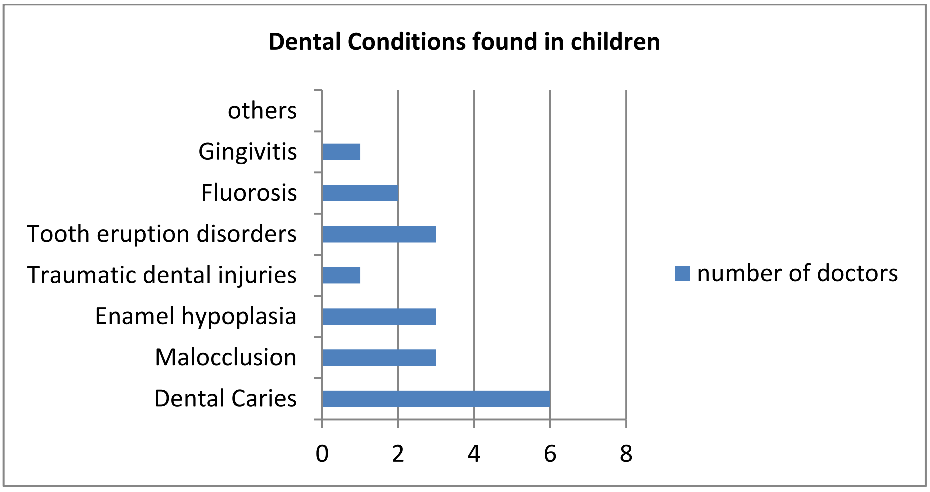

Fig.1 Survey of Dental Conditions from pedodontics.

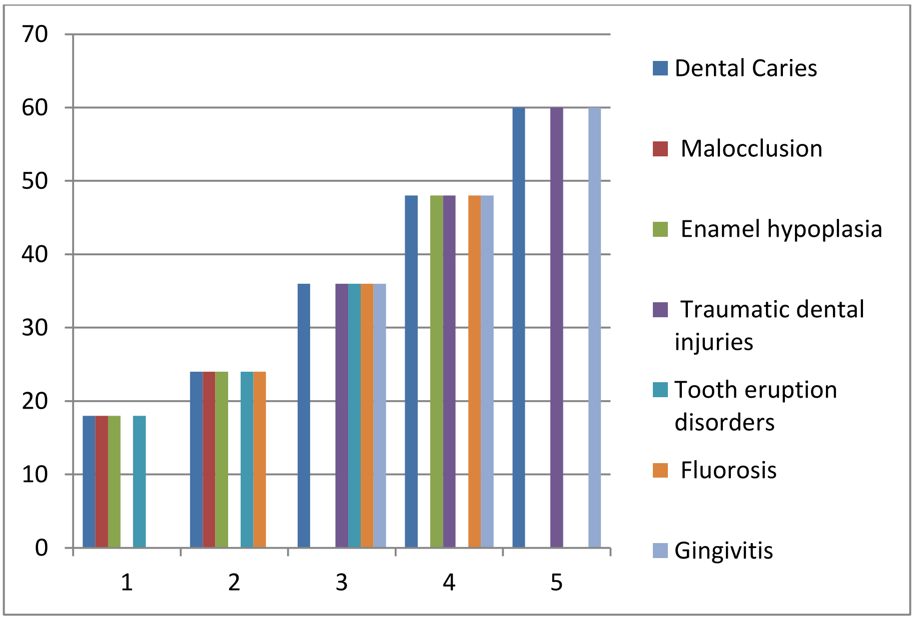

Fig.2 A survey of dental disease found at an age group (18 to 60 months)

2 Literature Review

[41] Ramos-Gomez et al. contribute significantly to the literature by showing that simple caregiver survey items, when processed via machine learning, can predict dental caries risk in young children (2-7 years) with moderate accuracy. While the work has limitations, it paves the way for more cost-efficient, scalable, and remote screening tools, particularly important in contexts where access to routine clinical dental examinations is limited. The study aims to evaluate whether a Random Forest machine learning algorithm, applied to parent-reported survey items, can predict active caries and caries experience in children aged 2–7. The dataset includes 182 parent-child pairs from Los Angeles County. Parents completed a 34-item survey about their child's oral health, behavior, demographics, access to dental care, etc. The children were clinically examined for caries.

[42] The paper aims to identify the key risk factors influencing dental caries in children aged 7 years and under It uses machine learning methods to enable **early** identification of high-risk children, so that preventive interventions can be more effectively targeted It demonstrates that machine learning, in particular Random Forests with interpretability measures, can identify key risk factors for dental caries in young children and support preventive strategies. For your research (extending across childhood to adolescence and possibly in the Indian context), this paper offers methodological lessons (choice of algorithms, feature selection, explainability), but also highlights where further work is needed (wider age span, imaging, longitudinal design, broader population).

C Kumar et.al. [10] reported a few machine learning algorithms such as Random Forest (RF), Decision Tree (DT), Logistic Regression (LR), and Naïve Bayes (NB) for providing a model for dental caries detection. Finally, the said algorithms are evaluated over the influencing parameters such as accuracy, precision, recall, F1-Score, and Mathews Correlation Coefficient (MCC). The empirical analysis shows that the DT provides a more accurate model with an accuracy level of 85.62%.

GA Şahin et.al. [11] Employed supervised learning, with models trained on labeled datasets to achieve precise diagnostic outcomes. This work highlights that while artificial intelligence and machine learning techniques, including convolution neural networks and U-Net, offer significant improvements in periodontal diagnostics, the choice of model and the quality of the dataset are crucial for performance. Hybrid approaches that combine automated and expert-driven methods might provide a balance between efficiency and accuracy. The successful integration of artificial intelligence into clinical practice requires continuous validation and adaptation to ensure that these technologies remain accurate and relevant.

MA Hasnain et.al. [12] Proposed IDD-Net (Identification of Dental Disease Network), a novel deep learning-based model designed for the automatic detection of dental diseases using panoramic X-ray images. The proposed framework leverages Convolutional Neural Networks (CNN) to enhance the accuracy and efficiency of dental condition classification, thereby significantly improving the diagnostic process. IDD-Net's performance is rigorously compared to four state-of-the-art deep learning models: AlexNet, InceptionResNet-V2, Xception, and MobileNet-V2. To tackle the issue of class imbalance, they employ the Synthetic Minority Over-sampling Technique with Tomek links (SMOTE Tomek), ensuring a balanced sample distribution that enhances model training. These findings underscore the transformative potential of IDD-Net as a reliable and efficient tool for assisting dental and medical professionals in the early detection of dental diseases. By streamlining the diagnostic process, IDD-Net not only improves patient outcomes but also has the potential to reshape standard practices in dental care.

MA Hasnain et.al. [13] evaluated the performance of all of the EfficientNet variants (e.g., EfficientNets B0-B7) to determine which one is the most effective model for detecting dental disease. Moreover, the Borderline Synthetic Minority Oversampling Technique (SMOTE)utilized to cope with the issue related to the minority classes contained in the dataset. To assess the efficacy of the model, various metrics are employed, including recall, accuracy, precision, loss, and F1-score. As a result, the performance of the EfficientNet-B5 model was superior to that of the other EfficientNet models.The results indicated that the EfficientNet-B5 model performs better than other EfficientNet classifiers, which supports dental professionals significantly in the recognition of dental diseases.

AF Makarim et.al. [14] compared several classification models to recognize human dental conditions to help doctors analyze patient teeth. They apply the YOLOv5, MobileNet V2, and IONet (proposed CNN model) as deep learning models to recognize the five common human dental conditions: normal, filling, caries, gangrene radix, and impaction.They tested the ability of YOLO classification as an object detection model and compared it with classification models.

P Choudhari et.al. [15] used to find various factors and its importance for the treatment. Furthermore, the paper critically evaluated the literature to describe various machine learning and deep learning algorithms used to ease and automate different dental procedures like reading x-ray, detecting oral diseases, predicting dental caries and recommended treatment etc.

S Anil et.al. [16] Introduced the fundamental concepts of AI, including machine learning and deep learning algorithms, and emphasizes their relevance and potential contributions to the diagnosis of dental caries. It further explains the process of gathering and pre-processing radiography data for AI examination. Additionally, AI techniques for dental caries diagnosis are explored, focusing on image processing, analysis, and classification models for predicting caries risk and severity.

IA Kang et.al. [17] Applied several machine learning algorithms were applied to data, and their performances were evaluated using accuracy, F1-score, precision, and recall. Random forest has achieved the highest performance compared to other machine learning methods, with an accuracy of 92%. The results of the proposed paper show that ML is highly recommended for dental professionals in assisting them in decision making for the early detection and treatment of dental caries.

MA Hasnain et.al. [18] Utilized dental radiographs as a source, convolutional neural networks (CNNs) were used to extract distinguishing features. To assess how well different CNN architectures performed in classifying dental diseases, popular models like VGGNet19, ResNet50, and DenseNet169 were used. The outcomes showed that deep learning models were effective at classifying dental diseases. The top-performing model outperformed on conventional machine learning methods.

The models were effective at distinguishing between various dental disorders, such as Healthy and affected teeth. The models also demonstrated good specificity and sensitivity, recall, precision, f1score and training testing accuracy highlighting their potential as trustworthy diagnostic tools.

R H Putra et.al. [19] aimed to assess the performance of the deep learning (DL) model for automated tooth numbering in panoramic radiographs. The training and testing process was carried out using You Only Look Once (YOLO) v4, a deep convolution neural network model for multiobject detection. The performance of YOLO v4 was evaluated using a confusion matrix. Furthermore, the detection time of YOLO v4 was compared with a certified radiologist using the Mann-Whitney test.The DL approach using the YOLO v4 model can be used to assist dentists in daily practice by performing accurate and fast automated tooth detection and numbering on panoramic radiographs.

S Minoo et.al. [20]utilized three convolutional neural network (CNN) architectures—VGG16, VGG19, and ResNet50—to classify teeth diseases from a dataset of labeled teeth images. Each model was trained and evaluated using 5-fold cross-validation to ensure robust performance. The results demonstrate that ResNet50 outperforms the other models with an accuracy of 95.23%.

A Katsumata et.al. [21] used to classify images with and without positive abnormal findings or to evaluate the progress of a lesion based on imaging findings. Region (object) detection and segmentation tasks have been used for tooth identification in panoramic radiographs. This technique is useful for automatically creating a patient's dental chart. Deep learning methods can also be used for detecting and evaluating anatomical structures of interest from images

.R Esmaeilyfard et.al. [22] aimed to investigate the accuracy of deep learning algorithms to diagnose tooth caries and classify the extension and location of dental caries in cone beam computed tomography (CBCT) images. The test dataset was provided to a multiple-input convolutional neural network (CNN). The network made predictions regarding the presence or absence of dental decay and classified the lesions according to their depths and types for the provided samples. Accuracy, sensitivity, specificity, and F1 score values were measured for dental caries detection and classification. This research demonstrates that deep learning models can accurately identify dental caries and classify their depths and types with high accuracy, sensitivity, and specificity.

AS AL-Ghamdi et.al. [23] proposed a convolutional neural network (CNN) that can do multitask classification by classifying the X-ray images into three classes: cavity, filling, and implant. In this paper, convolutional neural networks are taken in the form of a NASNet model consisting of different numbers of max-pooling layers, dropout layers, and activation functions. Initially, the data will be augmented and preprocessed, and then, the construction of a multioutput model will be done. Finally, the model will compile and train the model; the evaluation parameters used for the analysis of the model are loss and the accuracy curves.

A. Thulaseedharan et.al. [24] identified various dental diseases and the treatments for them by utilizing a dataset of 664 dental panoramic X-ray images which is considered a small number. These images have been used for training after being manually labeled for 9 separate classes. You Only Look Once (YOLO) version 5, a one-step search method primarily utilized for real-time object detection, is the deep neural network that was used. Bounding boxes helped identify six differential treatments and three classes of dental diseases.

K Kohinata et.al. [25] explored the feasibility of using deep learning for profiling of panoramic radiographs. A Neural Network Console (Sony Network Communications Inc., Tokyo, Japan) deep learning system and the VGG-Net deep convolutional neural network were used for classification. The proposed preliminary profiling method may be useful for preliminary interpretation of panoramic images and preprocessing before the application of additional artificial intelligence techniques.

F Oztekin et.al. [26] presented an explainable deep learning model for detecting dental caries. They tested three prominent pre-trained models, EfficientNet-B0, DenseNet-121, and ResNet-50, to determine which is best for the caries detection task. These models take panoramic images as the input, producing a caries–non-caries classification result and a heat map, which visualizes areas of interest on the tooth. The proposed explainable deep learning model diagnosed dental caries with high accuracy and reliability. The heat maps help to explain the classification results by indicating a region of suspected caries on the teeth. Dentists could use these heat maps to validate the classification results and reduce misclassification.

S Lee et.al. [27] developed a CNN model using a U-shaped deep CNN (U-Net) for caries detection on bitewing radiographs and investigated whether this model can improve clinicians' performance. The research complied with relevant ethical regulations.When three dentists detected caries using the results of the CNN model as reference data, the overall diagnostic performance of all three clinicians significantly improved.

JS Patel et.al. [28] developed and tested the PD prediction model using machine learning (ML) and electronic dental record (EDR) data that could provide large sample sizes and up-to-date information. The prediction model differentiated healthy patients *vs*. mild PD cases and mild PD *vs*. severe PD cases with an average area under the curve of 0.72.This pilot study demonstrated promising results in predicting the risk of PD using ML and EDR data. The model may provide new information to the clinicians about the PD risks and the factors responsible for the disease progression to take preventive approaches

.L R Mehta et.al. [29] aimed to identify the most suitable deep learning model for early detection of dental caries in a new database of dental diseases. The study compares the performance of residual and dense networks using standard performance metrics. Dental caries is categorized into four classes based on dental practitioner recommendations. The DenseNet201 algorithm shows promise for detecting and classifying dental caries in digital RGB images.

AJM Rani et.al. [30] provided a detailed account of the procedures that were carried out, including the categorization and segmentation of dental pictures, as well as the pre-processing techniques that were utilized. During the pre-processing stage, a histogram that is based on an adaptive technique is utilized to extend the contrast and equalize the level of illumination throughout the whole radiographic X-ray two-dimensional dental image. The dental picture was processed using deep learning-based techniques known as Improved Neural Network Strategy (INNS) and Support Vector Machine (SVM) in this research. The results of this research suggest that these approaches have the potential to produce promising results with greater accuracy rates.

M Aqeel et.al. [31] presented a comprehensive approach to dental cavity analysis, spanning localization, quantification, and visualization. Our methodology leveraged a diverse dataset of colored dental images that had been meticulously augmented and annotated. The You Only Look Once model was employed for precise dental cavity localization, providing bounding box predictions. Remarkably, these results were obtained based on images from standard device cameras. Subsequently, we introduced the use of the segment anything model segmentation model, known for its zero-shot generalization capabilities, to focus on the exact areas of dental cavities. This approach enhanced the granularity of our analysis, providing dental professionals with detailed visualizations for precise diagnosis. During the quantification phase, we extracted cavity areas from bounding box coordinates, enabling accurate measurement of cavity sizes.

C Kim et.al. [32] designed a model to assess tooth-related diseases in panoramic images by using artificial intelligence in real time. This model can perform an auxiliary role in the diagnosis of tooth-related diseases by dentists and reduce the treatment planning time spent through telemedicine. To learn the model, the fast region-based convolutional network (Fast R-CNN), residual neural network (ResNet), and inception models were used. Learning about the 5 tooth-related diseases completely did not provide accurate information on the diseases because of indistinct features present in the panoramic pictures. Therefore, 1 detection model was applied to each tooth-related disease, and the models for each of the diseases were integrated to increase accuracy. The Fast R-CNN model showed the highest accuracy in the real-time diagnosis of dental diseases and can therefore play an auxiliary role in shortening the treatment planning time after the dentists diagnose the tooth-related disease.

J Rashid et.al. [33] developed Mouth and Oral Diseases Classification using InceptionResNetV2 Method to identify diseases such as gangivostomatitis (Gum), canker sores (CaS), cold sores (CoS), oral lichen planus (OLP), oral thrush (OT), mouth cancer (MC), and oral cancer (OC). The new collection, termed "Mouth and Oral Diseases" (MOD), comprises seven distinct categories of data.

B Beser et.al. [34] evaluated the effectiveness of YOLO-v5 in the automatic detection, segmentation, and numbering of deciduous and permanent teeth in mixed dentition pediatric patients based on PRs.YOLO-v5 based models can have the potential to detect and enable the accurate segmentation of deciduous and permanent teeth using PRs of pediatric patients with mixed dentition.

BT Çiftçi et.al. [35] analyzed the risk factors that affect oral health in adults and to evaluate the success of different machine learning algorithms in predicting these risk factors. The preprocessed dataset was analyzed using various machine learning algorithms, including naive Bayes, logistic regression, support vector machine, decision tree, random forest and Multilayer Perceptron algorithms. Pearson's correlation test was also conducted to assess the correlation between participants' DMFT scores and oral health risk factors .The results of this study show the potential of machine learning algorithms for predicting caries risk groups, and these algorithms are promising for future studies.

SO Zayed et.al. [36] developed a Computer-Aided Software for accurate diagnosis of oral diseases based on clinical and histopathological data inputs. The correct diagnosis rate of DODS was comparable to oral pathologists using standard microscopic examination. The DODS program could be utilized as diagnostic guidance tool with high reliability & accuracy.

W Li et.al. [37] proposed to screen the existence of gingivitis and its irritants, i.e., dental calculus and soft deposits, from oral photos with a novel Multi-Task Learning convolutional neural network (CNN) model. the model can also localize the three types of findings on oral photos with moderate accuracy, which enables the model to explain the screen results. By comparing to general-purpose CNNs, they showed our model significantly outperformed on both classification and localization tasks, which indicates the effectiveness of Multi-Task Learning on dental disease detection.

A Qayyum et.al. [38] presented an efficient self-training-based method for caries detection and segmentation that leverages a small set of labeled images for training the teacher model and a large collection of unlabeled images for training the student model. We also propose to use centroid cropped images of the caries region and different augmentation techniques for the training of self-supervised models that provide computational and performance gains as compared to fully supervised learning and standard self-supervised learning methods.

D Saini et.al. [39]detected dental caries using digital color image at an early stage so that the treatment can be performed easily and effectively. This classification also suitable for tele dentistry as tele informatics oral health care system for this proposed work we implemented the deep learning model is convolution neural network (CNN). We have trained deep learning different models of CNN; they are Visual Geometry Group (Vgg16 & Vgg19) Inception-V3 and Resnet50. Training, validation, and testing has been performed on binary dataset with caries and without caries images. The classification accuracy is achieved using Vgg16, Vgg19 Inception v3 and Resnet50 models and the highest accuracy is achieve during Inception v3.

H.S. Schuch et.al. [40] predicted foregone preventive dental care among adults overall and in socio demographic subgroups and to assess the algorithmic fairness. Findings of this prognostic study using cohort data suggest that tree-based ensemble machine learning models could accurately predict adults at risk of foregoing preventive dental care and demonstrated bias against underrepresented socio demographic groups. These results highlight the importance of evaluating model fairness during development and testing to avoid exacerbating existing biases.

3 Result :

The reviewed literature demonstrates that Artificial Intelligence (AI) and Machine Learning (ML) approaches have shown strong potential in the early detection and risk prediction of dental caries and other dental diseases across childhood and adolescence.

4 Conclusion:

In summary, AI-based diagnostic frameworks hold substantial promise for shifting oral health care in India from a reactive, treatment-oriented model toward a preventive, prediction-driven paradigm. By enabling early detection and targeted interventions among children aged 3–18 years, AI can contribute meaningfully to reducing the long-term burden of oral diseases and advancing public health outcomes

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