An Intelligent way of detecting dental diseases and recommendation of possible treatments

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Abstract:

Nowadays deep learning is one of the buzzwords heard mostly in various sectors to solve the problems which they are facing in efficient way. Healthcare sector is also not an exception for this. Dentistry is the healthcare field where deep learning has amazing benefits in automating various dental procedures. Most of the treatments for treating infected tooth are recommended based upon analysis of various clinical as well as non-clinical factors. The review includes studies 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.

Keywords: Endodontic, deep learning, machine learning, dental caries, oral diseases, root canal, dental treatment.

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Introduction

All organizations have inculcated different techniques of Artificial Intelligence (AI) in their various sectors in order to automate different processes and to avail the benefits provided by the technology. Healthcare is also not the exception for this. Various translational applications provided by Artificial Intelligence have accumulated substantial amount of interest in the field of medicine [1]. Machine learning and deep learning are types of Artificial Intelligence which consists various algorithms use to sever different purposes of the applications. Linear regression, logistic regression, K-mean clustering, Support Vector Machine (SVM), Random Forest, Naïve bayes, K-Nearest Neighbor(K-NN), etc. are different algorithms of machine learning having various applications in medicine. Artificial Neural Network (ANN), Convolutional Neural Network (CNN), Recurrent Neural Network (RNN) etc. are the deep learning algorithms providing good efficiency in automating different tasks performed by clinicians. Dentistry is one of the fields of medicine, which concerned about prevention and diagnosis of oral diseases and its treatments. Tooth decay, cavities, root infection, gum disease, sensitive teeth, cracked or broken tooth, receding gums, Enamel erosion, etc. are some of the dental diseases. Traditionally these diseases were diagnosed by physical examination of tooth which requires expertise to recommend proper treatment. Nowadays, X-ray images or Panoramic Radiographs (PR) are the tools used to diagnose these diseases and recommending possible treatments [2, 3, 4]. Cleanings, fluoride treatment, fillings, root canal, implant, tooth extraction, etc. are some of the treatments recommended by dentist based on the infection caused in tooth. Though the tools X-Ray or PR images reduced the errors occurred by traditional methods, expertise in the field is still requiring for recommending the exact treatment by examining the images. Machine learning and deep learning paved way in the dentistry to assist the clinicians by automating the process of dental disease diagnosis and recommending the possible treatments.

Presented here the broad overview of the machine learning and deep learning algorithms usage in dentistry. A review of the different dental diseases, role of AI in diagnosing and recommending the treatment, different predictors in tooth anomaly detection and prediction of the treatment, and characteristics of included studies. A brief insight into some research gaps along with future trends is also included.

Different Dental Diseases:

Table 1: Some common dental diseases

Sr.no.	Dental diseases	Definition
1	Dental Caries	When tooth adherent bacteria metabolizes sugar leads to a generation of acid, which over a period causes dental decay by damaging outer enamel of the tooth and attacking on softer dentin layer beneath the enamel.
2	Gum disease	Plaque generation causes bacterial infection is responsible for red, swollen gum that bleeds easily.
3	Bad breath	Also known as halitosis. Dry mouth, poor oral hygiene, medication, infection, acid reflux etc. are the main causes of bad breath.
4	Cracked or broken teeth	Mouth piercing, injury, chewing hard food, grinding teeth while sleeping causes cracked or broken tooth, leads to a lot of pain depending upon extent of the damage.
5	Sensitive teeth	When enamel is worn away and the dentin is exposed. Major cause of it is tooth decay. Other possible causes include root infection, gum disease, enamel erosion etc.
6	Receding Gums	Brushing teeth too hard, high blood pressure, poor oral hygiene, hormonal fluctuation in woman, etc. are some of the causes of receding gums.
7	Root infection	Base of the tooth also known as root is infected and swollen because bacteria attack.
8	Enamel erosion	Maximum intake of sweet and acidic food over a long period leads to an erosion of enamel slowly and steadily.

Role of AI in diagnosing dental diseases and recommending the treatment

One of the most prevalent dental diseases is dental caries. Dental caries is the destruction of dental hard tissue at crown or root level by acidic byproducts generated through bacterial fermentation of dietary carbohydrates [5]. If it will not be detected and treated on time then results into a tooth extraction. Hence, for better quality life it is necessary to minimize the impact of caries for individual. Machine learning and deep learning algorithms can be used to predict the chances of person to develop root caries [4, 5, 6, 7, 8] as well as to recommend the possible treatment [2, 6]. These algorithms will detect and predict the treatments by considering an association between different parameters responsible for developing a dental caries for individual. Various statistical measures are used to calculate the significance of these parameters, for example F-score is used to estimate top 15 parameters to build machine learning model [5].

LASSO algorithm is also used to select the important features in the same aspect [6]. In [7] Generalized Regression Neural Network (GRNN) was constructed for predicting dental caries. GRNN model found to be better as compared to traditional unconditional logistic regression in terms of consistency, sensitivity, and specificity. GRNN is an early warning model in order to early diagnosis and treatment planning for elderly people having high risk of caries. In [5] SVM was found to be the best algorithm among XG-boost, random forest, k-nearest neighbor and logistic regression in classification result. By deep Convolution Neural Network technique, general practitioner will be benefitted in order to enhance their accuracy of diagnostic and predict accurate dental decay treatment from 4 treatments i.e., fluoride, root canal, dental filling, and tooth extraction [2]. In [3] hybrid, deep learning and machine learning concept is used to detect caries/periapical infection, altered periodontal bone height, and third molar impaction using panoramic dental x-ray. Convolutional Neural Network and Support Vector Machine algorithms are used for feature extraction and classification respectively. Three approaches were used for the training process. First is training baseline SVM, second involved training vanilla CNN and third include CNN-SVM where the feature extracted by CNN and these features provided as input to SVM for classification. All images were preprocessed to enhance using iterative algorithm for better feature extraction for both SVM and CNN algorithm. Each model was evaluated through accuracy, sensitivity and specificity performance metrics. Author has claimed that CNN-SVM performed better as compare to other model used in the paper for comparison. Artificial Intelligence based computer vision technique is used to lessen the burden of clinician by detecting 17 fine grained dental anomalies which need to be detected to cure on time leads to healthy oral life of patient [4]. In [4] author has used faster R-CNN for dental anomaly detection. The Deep learning model can be used in image segmentation. U-net, Xnet, Seg-Net and U-Net+DenseNet 121 were used for periapical radiographs segmentation and compared for diagnosis of caries, IRR-Interradicular radiolucencies, ABR- alveolar bone recession. The best segmentation performance was achieved through U-Net and overall best performance on validation is obtained through U-Net+DenseNet121 [9]. In [9] the author used Intersection over Union(IoU) and Dice as a two evaluation metrics. Early diagnosis of oral cancer was done by the classification of images done through ResNet-101 CNN deep learning model with the depth of 101 layers. ResNet-101 CNN achieved 87.07% F1-score for identification of lesion containing images [10].

Different predictors in tooth anomaly detection and recommendation of the treatment

Various clinical and no-clinical parameters need to be considered while anomaly detection and to recommend the appropriate treatment. Lifestyle and demographic parameters can be used with machine learning algorithms to identify chances of person to develop root caries. The age was found to be a most important parameter or variable in identifying root caries [5]. Gum health is the significant feature as compared to other parameters in dental care recommendation [6]. Success of endodontic and re-endodontic treatment depends upon various clinical factors such as periodontal disease, the presence of pulpal inflammation or infection of primary tooth, broken instruments, residual infected pulp tissue, root canal underfilling, root canal overfilling, unfiled canal or missed canal, and mechanical perforation [11]. Failure is observed more in elderly people because of calcified canal, poor oral hygiene and uncooperative behavior [11]. In [12] author has mentioned that during root canal treatment, periarticular inflammation is caused because of extrusion of microorganism or debris leads to a post endodontic pain. Operative procedure error plays very important role in root canal treatment to decide failure and success of the treatment. Hence it need to be analyzed properly to avoid tooth loss in the future. Endodontic treatment planning, anesthesia, pulp and periapical disease diagnosis, access cavity preparation, isolation with rubber dam, root canal filling, Postoperative pain, follow-up and restoration of an endodontically treated tooth are the common procedural errors within the clinical operative sequence. Absence of periapical rediolucency in the image and clinically absence of pain, tooth in definitive restoration and masticatory function indicates success of treatment. Whereas presence of a periapical rediolucency in the image and clinically patient having pain, swelling, temporary restoration, sinus tract indicates failure of root canal treatment [13].

Table 2: Different factors responsible for root canal failure [11,13]

Sr.No.	Clinical Factors	Non-Clinical Factors	Operative procedure error
1	Periapical rediolucency	Age	Broken instruments
2	Root Fracture	Poor oral hygiene	Untreated root canals
3	Perforation on site	Non-Vegetarian	Unfilled and Missed canals
4	Broken tooth	Uncooperative behavior	Overfilled canals
5	Curved root canal	Smoking and drinking	Perforations
6	Insufficient Periodontal support	Demographic area	Poor coronal restorations
7	Pulp stones	Education of patient	
8	Vertical fracture in root		
9	Tooth Location		
10	Root resorption		
11	Periapical abcess		

Table 3: Characteristics of the included studies

Sr. no	Author	Object	Total Sample Size	Method /Algorithm	Results	Limitations
1	Bouchahma, M. at al.[2]	Bulid a model to predict accurate dental decay treatment using deep learning algorithm.	200	CNN	Overall accuracy treaments is 87%	Limited data size
2	Verma, D. at al. [3]	Build a model for classification of image as “Normal” or “Anomalous”.	366. After augumentation 1098	SVM, vanilla CNN, SVM-CNN	1. Hybrid model outperformed 2.accuracy : 98.69%, specificity: 98.5% and sensitivity: 97.9%	unable to detect specific disease
3	Lee, S., Kim, D. and Jeong, H. [4]	build model to detect 17-fine grained dental diseases which are critial to patient oral health	23000	Faster R-CNN	Over 95% specificity for most classes	Image labeling based on only one expert
4	Hung, M. at al. [5]	Prediction of the root caries using machine learning algorithm	5135	SVM, XG-boost, random forest, K-NN, logistic regression	1. dominant factor: Age 2. Best performance by SVM accuracy = 97.1%, precision =95.1% , sensitivity= 99.6% Specificity=94.3%	1. Data is more representative 2. longitudinal study needed 3.F-score selected not directly co-related features

5	Hung, M. at al. [6]	Urgency of the patient to see the dentist is recommended using Machine learning models	2141	SVM, CART, random forest, K-NN, logistic regression	1. Significant feature: Gum Health 2. Random forest and CART outperformed accuracy and precision :84% . Specificity and sensitivity is 92%	1. Model complexity is compromized using LASSO 2.Efficient only for cross-sectional study
6	Liu, L. at al.[7]	Build prediction model assessing a risk of dental caries among the geriatric residents of Liaoning, China using GRNN	1114	GRNN	1. ROC curve : 62.2% (P = 0.002) 2. Sensitivity : 85.16% , specificity :70.27%	1. Difficulty in finding each variable contribution 2.Bias may introduced due to reading limitaions of patient
7	Lee, J. at al. [8]	Detection and diagnosis of dental caries through PR images using deep learning .	3000	GoogLeNet Inception v3 CNN	Premolar model outperformed in terms of AUC with p<0.001	1. Clinical parameters not included 2. Study included permanent teeth only
8	Iqbal, A. at al. [11]	Evaluate different clincial as well as non clinical factors responsible for endodontically treated tooth	90	statistical analysis through cross-sectional study	1. General dental practitioner failure rate: 78.8% , specialist failure rate: 21.1% 2. Important factor: Age , tooth location	1. Limited data size 2. General practionar experiance data is not available
9	Khan, H. at al. [9]	Build model to detect features from PR images automatically using deep learning and semeantic segmentation	206	U-net, Xnet, Seg-Net, U-Net+DenseNet 121	1. In validation U-Net+DenseNet121 outperformed mIoU = 0.501 , Dice coefficient = 0.569 2. In test phase best U-net outperformed mIoU = 0.402 and Dice coefficient = 0.453	1. Considered interpreation of 3 experts while labeling images as a ground truth 2. Limited training and testing data
10	Bufersen, S. at al. [14]	Investigate the variables associated with failure of ETT among 6 to 18 years old and survival of it	341	Statistical treatment of survival times using Kaplan-Meier method	1. Significan factor: Age 2. Not associated paramenters: tooth type, jaw type and gender	1. No data regarding periapical status of ETT, caries, restorations, fractors.
11	Olcay, K. at al. [20]	To review the factors related to endodontically treated tooth failure and extracted tooth underwent unsuccessful endodontic treatment.	1000	statistical analysis through cross-sectional study	Main responsible factors: endodontic and restorative Less reponsible factors: orthodontic reasons	Unable to obtain reliable data from patients

Proposed Model for predicting longevity of root canal treatment:

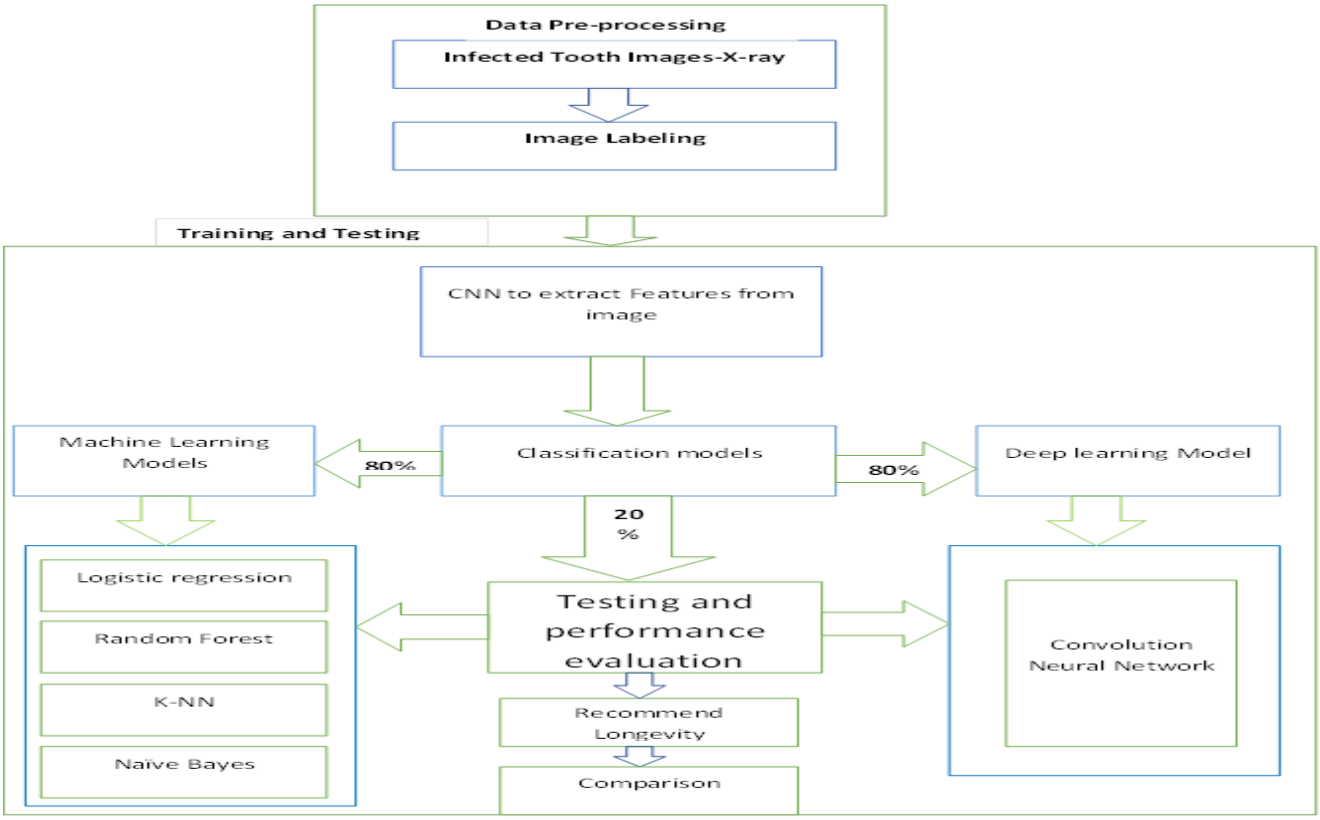

Fig 1 : Predicting longevity of root canal treatment

Discussion:

Machine learning and deep learning algorithms are used to serve different purposes in dental field. These algorithms are used for reading X-ray automatically by extracting factors from it and based on the status of the different factors; a level of infection of the tooth is predicted [5]. An age was the most important parameter in detecting root caries and other oral diseases, it will further help in recommending the possible treatment using machine and deep learning algorithms. This automatic detection of disease and prediction of the treatment will assist doctors' especially new comers in the field. However, a major concern is the lack of availability of data. A general dental practitioner has high failure rate in endodontic treatment (78.8%) while specialist have lower failure rate (21.1%) [11]. As prediction efficiency of machine and deep learning models will be improved with a large size of data, huge data availability is an important requirement. Hybrid model has better performance over other models in an anomaly detection. Accuracy, specificity and sensitivity obtained through the hybrid model is 98.69%, 98.5% and 97.9% respectively. Data set selected to train the model is from specific area leads to a selection bias problem while training the model. Also, Efficiency of the model is proved by comparing it with the other model but data set used in all models was different [3].

Dental treatments are costly as well as time consuming hence accurate prediction of the treatment will increase the quality of service. If the survival of the treatment is known before starting of the treatment, then a patient can choose the treatment accordingly. It will save his both money and time. Machine and deep learning approach can be used in deciding the survival period of the treatment.

Conclusion

Artificial Intelligence has paved its way in almost all sectors including healthcare. Dentistry is the field where AI has shown good results in solving various problems faced by clinicians. Clinician are using AI models to read the X-ray accurately and diagnosing different dental diseases and level of infection. AI can also be used to recommend the treatment depending upon the infection. This paper has reviewed literatures where applications of AI in dentistry is studied and experimental analysis is shown by implementing different models built using machine learning and deep learning algorithms. Though artificial intelligence is being used in dentistry in various problem solving, it's usage can be extended by using it to determine the survival period of any treatment. It will assist patients as well as doctors to choose the appropriate treatment which in turn gives good quality of service to the patient.

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