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A Systematic Review on Oral Cancer Diagnosis and Prognosis using Machine Learning Techniques

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ABSTRACT

One of the most dangerous and irrecoverable cancers which exists in the oral fissure is oral cancer or mouth cancer. It arises from the oral cavity and neck. It disturbs lips and the main parts of tongue, mouth roof and floor. It also affects our oropharynx. The principal factors for increasing mouth cancer is excessive use of tobacco, alcohol, cigarettes and human papilloma virus (HPV) infection. The diagnosis of oral cancer at an initial stage with precise treatment can save the survival of numerous people. This work provides a systematic review of diagnostic and prognostic of Oral Caner using machine learning techniques and highlights certain limits and concerns of clinicians towards the application of machine learning-based models for daily clinical practice.

Keywords— Oral cancer, Squamous cell, Data mining, Deep learning, Classification.

I. INTRODUCTION

Oral cancer (OC) is one of the most lethal diseases [1] and has been a main community health concern around the world. It develops in the mouth or throat tissues and belongs to head and neck cancers. Mostly, it develops in the squamous [2] cells found in mouth, tongue [3], and lips [4],[5]. Oral cancers are identified after they have been spread to the lymph nodes of the neck. According to the report of World Health Organization, approximately six lakh new oral cancer cases and more than three lakh deaths are stated every year [6]. Oral cancers include the cancers of the lips, inner lining of cheek, tongue, mouth. Its discovery and analysis is very imperative or else it can be lethal .The oral cancer comprises four stages starting from stage 0 to stage 4. The survival rate for stage 1 is around 80%, whereas for the stage 2 and 3 it is less than 20% [7],[8].

Oral Squamous Cell Carcinoma (OSCC) [9] is a malignant tumour that may exists somewhere inside the oral cavity and includes 90% of the disease [10],[11]. Therefore early diagnosis of a cancer type have become a necessity in cancer research. The ability of ML tools to detect key features from composite datasets reveals their significance. Oral cancer is caused due to use of tobacco, including cigars, pipes, chewing tobacco[12],[13] human papillomavirus infection, snuffs, or alcohol consumption [14],[15]. OC is related with numerous factors, and the life time rate after treatment is also unpredictable [16],[17].

Generally, labelled premalignant oral lesions are leukoplakia, erythroplakia, lichen planus, and sub mucous fibrosis [18],[19] are also common between the risk population. Distinguishing these lesions from the malignant lesions are also very significant. The primary features like age, gender, and tobacco habits may also disturb the prediction of OC [20],[21].

In this paper, a detailed review is made regarding the diagnosis and prognosis of Oral Cancer using machine learning techniques. The aim of using ML techniques in health care is to generate a model that can be utilized to forecast the medical outcomes of the patient from multivariate data. The main motivation of this work is therefore to review and provide a complete and comprehensive summary of all the evidence related to the use of ML algorithms as a non-invasive tool to evaluate the Oral Cancer prognosis and stratify the risk of recurrence.

II. LITERATURE REVIEW

The detection of oral cancer (OC) in advance definitely rises survival rates of patients. The Fig.1 shows the research direction's map on the diagnosis of OC.

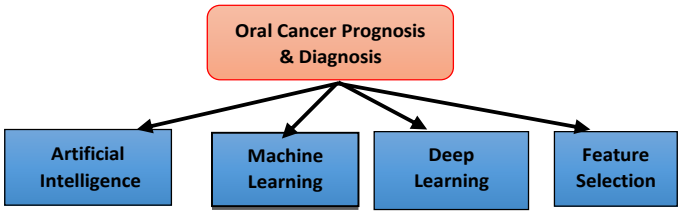

Fig.1. Research Direction's Map

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2.1. Artificial Intelligence Techniques for Oral Cancer

Recently, there has been vibrant interest in applying the artificial intelligence (AI) techniques for prognosis and diagnosis of Oral Cancer. AI techniques includes artificial neural networks (ANN), genetic algorithms and fuzzy logic etc. In [22], a detailed review was made using artificial intelligence for Oral cancer detection. A study was conducted in [23] by applying ANN for early detection of OC, employing technology which is digitization of the cytology slides. The effectiveness of AI was equated with traditional cytology and histology. In this work,11,981 prepossessed images were used based on the risk stratification model. The ANN-based model achieved 93% accuracy for improved malignant detection and 73% accuracy for potentially malignant lesion.

The paper [24] used AI technology for detecting OC on smart phone-based images. Auto fluorescence and white light imaging techniques were applied to the pictures, and these pictures were given to AI algorithms for identifying oral malignancy. However, for further validation of this study, large population of images need to be used. A similar work was done in [25] by using PCA and ANN for auto fluorescent spectral images. The performance of ANN was somewhat better than PCA. The main benefit of this method was that spectral image uses a slightly invasive technique and there is no necessity for using biopsy. Musulin et al conducted a study in [26] using AI for detecting OC on histology images.

In [27], a similar study was conducted on clinical images of patients using CNN method. The results showed that CNN was better at discriminating malignant lesions as mild or severe. A literature review was made in [28] to highlight the features of precancerous and cancerous oral lesions on OCT images using AI techniques and assisted in screening and diagnosis of such pathologies. The effectiveness of AI in predicting oral cancer was analysed in [29] based on the risk habits and demographic profiles in a Malaysian cohort. The prediction was done by using fuzzy regression model, fuzzy neural network model, and clinician opinion. The results indicated that AI-based neural network and fuzzy regression model achieved better accuracy than human opinion in forecasting the OC.

A systematic literature review was made in [30] to provide a comprehensive review of the state-of-the-art approaches reported in carcinoma diagnosis [31] using histopathological images. The review in [32] described the use and diagnostic accuracy of AI methods for detection and grading of potentially malignant and cancerous head and neck lesions using whole slide images (WSI) of human tissue slides. Many researchers used AI techniques for Oral cancer prognosis and diagnosis such as [33],[34],[35].

2.2. Machine Learning Techniques for Oral Cancer

Machine learning (ML) is a subset of artificial intelligence (AI) that permits applications to develop more precise at forecasting results without being explicitly programmed to do so. ML algorithms accepts historic data as input in order to predict novel output values. It contains four different types of techniques such as supervised, semi-supervised, and unsupervised and reinforcement techniques.

In [36], machine learning techniques were used with gene expression profiling to forecast the likelihood of oral cancer progress based on malignant transformation of oral premalignant lesions. The analysis was carried out using 86 patients, 51 of them were oral cancer patients and 31 remained cancer free. Deep learning techniques along with support vector machine and other methods were compared and correlated based on measures such as sensitivity and specificity and accuracy. The deep learning with the Fisher discriminant analysis yielded highest accuracy and obtained 96.5%, 98.1%, and 94.2% for accuracy, sensitivity, and specificity values. This can be considered as an enhancement compared to preceding results using traditional statistical methods, which showed a misclassification rate of 16%, with 91% sensitivity and 76% specificity [37].

A study was conducted in [38] using machine learning techniques to oral cancer prediction of 674 patients. It used decision tree and artificial neural network which then made the basic methods of random forest and deep learning. This analysis does not consider the time to event nature and assessed the status of disease at 5^{th} year. Even though, it was not an existence analysis considering time element, it was grounded on up to date oral cancer patient dataset. It was an early attempt using machine learning to oral cancer survival likelihood.

In [39], Chang et al. stated that 93.8% of accuracy with AUC of 0.90 in foretelling oral cancer patients' prediction. The study used 31 oral cancer patients' clinic pathologic status and genomic markers. Owing to small size of the database, only 5-fold cross-validation was used. The metrics such as accuracy and AUC were used based on disease status at a particular time point, and the time to event element was not used in this study. The machine learning methods such as random forest, CNN, SVM were applied on histopathological images in [40]. Before performing classification, feature extraction was done using principal component method. Marc et al [41]designed an automatic technique for exact precision of OSCC diagnosis using deep learning technologies on CLE images. The results were compared with textural feature-based machine learning techniques that specify current state of the art.

Sunil et al classified the stages of oral cancer into two types namely pathological and clinical in [42]. Numerous predictive and primary active tools have been generated for Tumour-Node-Metasis (TNM) stages classification. The classification precision of the TNM staging method was compared with the Linear Layer Neural Network. In [43], CT image of oral cancer patients were pre-processed through Adaptive Median Filter and classified using SVM.

The work proposed in [44] classifies oral cancers at a primitive stage and the type of tumour was recognised by using

Marker Controlled Watershed segmentation. The features extracted from this images were given into SVM Classifier for classification.

The paper [45] used SVM classifier to detect OSCC tumours by analysing expression profiling [46] on patient and mining RNA plus microarray analysis a gene expression signature forecasts OSCC tissue from normal. The objective of this paper [47] was to predict the primary stage of oral cancer using Naïve Bayes, Multilayer Perceptron, K-Nearest Neighbours and Support Vector Machine methods. They resulted in oral cancer stage and analysed an increase in classification accuracy. In [48], the researcher aim was to compare the classification accuracy of the TNM staging system using Multi-Layer Perceptron (MLP) and Gaussian Mixture Model classifiers. The results showed that both classifiers provided a better result as average accuracy for the stages. Extreme Learning Machines (ELM) was used as a post classifier later for the oral cancer analysis and the performance of ELM classifier was compared with performance of both GMM and MLP. The motivation of this researcher was to classify dental X-rays images into normal or decayed and developed a new model to find dental issues in X-ray images using deep neural network technology [49].

The paper [50] conducted a comparative study of using machine learning techniques for cancer prognosis and prediction. The study employed ANN, SVM, BN and decision tree classifiers. The survey of different neural network techniques was given in [51] for cancer classification in medical science. To determine the current status of the application of these learning models as adjunctive decision-making tools in oral cavity cancer management, this

A systematic review was made with the aims to summarize the accuracy of machine-learning based models as adjunctive decision-making tools in oral cavity cancer management in [52]. They also found that models containing molecular markers in training data had better accuracy values for malignant transformation, treatment response, and prognosis prediction. In this study [53] ,an analysis of imbalanced classification problem on oral cancer prediction was performed using crossover approach of SMOTE and Random Under sampling.. The proposed algorithm yielded better class imbalance solution and better performance in classification.

An analytical model using Support Vector Machines (SVM) with a hybrid feature selection method Hybrid Correlation Evaluator and Linear Forward Selection was developed in [54] to diagnose the stages of oral cancer patients. This study [55] provided a review of diagnostic and prognostic uses of machine learning algorithms in oral squamous cell carcinoma[56] and highlights the confines and concerns of clinicians to the application of machine learning-based models for daily clinical practice. In [57], various data mining methods were compared using WEKA tool for classification of oral cancer.

The paper [58] used digital image processing to classify the cancer cells in the oral area. This work used three techniques such as the bag histogram of oriented gradients, wavelet features and the Zernike Moment characteristics-extracting methods. After retrieving the texture characteristics, the fuzzy particle swarm optimization algorithm (FPSO) was applied to extract the best characteristic.

An integrated approach was used in [59] that combines the clustering and classification methods to determine the differences between the symptoms shown in past cases where patients died from or survived oral cancer. Decision tree and artificial neural network, were employed to investigate the past cases of oral cancer, and their performance was compared with that of logistic regression. Both decision tree and artificial neural network models showed superiority to the traditional statistical model. The paper [60] applied a method for cancer detection and prevention based on association rule mining. A survey on various methods used by the researchers for classification of oral cancer detection at an earlier stage has been given in [61].

Chuang et al. [62] considered DNA repair genes by selecting a single nucleotide polymorphisms dataset with 238 records of oral cancer patients for disease prediction. The results showed that the performance of the holdout cross validation was better than cross validation and the best classification accuracy is 64.2%. Gadewal et al. [63] have expanded the oral cancer gene database to 374 genes by adding extra 132 gene to enable fast retrieval of updated information. In [64] Naïve Bayes classifier was used to predict the recurrence of oral cancer in patients using WEKA and the results were compared with Random Forest algorithm.

In [65], authors investigated the Squamous Cell Carcinoma Recognition using Image Processing. This method detected disease quickly and found the exact location of this disorder and calculates the growth of this disease in lower lip. The paper [66] designed a hybrid models using classification and association techniques for early detection and prevention of oral cancer. The classification models and association rules were evaluated using various estimation parameters. In this paper [67], three predictive models were proposed using Single Tree, Decision Tree Forest and Tree Boost to identify the most effective model for predicting the survival rate of oral cancer in patients who visit the ENT OPD. For all three models, it was observed that there is no misclassified row in any category and all cases have correctly been classified. The sensitivity and specificity of these models is 100 %. The Genetic based ID3 algorithm was proposed in [68] for identifying oral cancer data.

2.3. Deep Learning Techniques for Oral Cancer

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Deep learning is a sub-part of AI, which takes higher level features from the data, for instance, text, pictures, or sound. It can provide better and more effective processing models. In paper [69], deep learning technique was used to predict Extra Nodal Extension (ENE) of 270 head and neck cancer patients CT data before going for surgery. Among them, 106 were oral SCC patients. The previous studies have showed that area under a receiver operating characteristic curve (AUC) values ranging from 0.65–0.694, whereas using deep learning model achieved an AUC of 0.91, thus showing the potential of the deep learning model for use as a clinical decision-making tool to help guide head and neck cancer patient management.

In this study [70], the researcher used CNN classifier to identify cancer on OSCC, Thyroid cancer and head and neck sample tissues. The results indicated that CNN produced 80% accuracy in detecting cancer. In this research work [71], they have developed an automated computer aided deep learning algorithm for oral cancer detection by investigating patient hyper spectral images.

In the paper [72], a method was proposed for detecting cancers present in mouth by using Orthopantomogram. A morphological watershed algorithm was used to preserve these edge details as well as prominent watershed on images leads to over segmentation. In the paper [73], hybrid model was proposed by using Relief F-GA feature selection and ANFIS classification. . The proposed prognostic model was experimented on two groups of oral cancer dataset which consist of clinicopathologic markers and genomic markers. It is experimented that that the proposed model is more accurate with the use of both types of dataset and the other methods of artificial neural network, support vector machine and logistic regression. This prognostic model can be used to help clinicians in the decision.

The objective of this paper [74] was to compare the Multilayer Perceptron Neural Network Model and Tree Boost Model for predicting the malignancy in 569 patients who visited the ENT OPD. This study showed that both models were optimal for predicting malignancy in patient. The aim of this paper [75] was to develop and validate a machine learning based algorithm that can offer survival risk stratification for patients with advanced oral cancer who have comprehensive clinic pathologic and genetic data.

Two Convolutional Neural Networks such as Inception-v3 and Resnet50 were used as feature extractors in [76] and then the derived features were feed as input to Multi-class Support Vector Machine and Random Forest for classification of Oral Squamous Cell Carcinoma into various stages. In [77] , Fuzzy Cognitive Map was proposed for classification of lesions. The map was designed using five Grey Level Co-occurrence Matrix (GLCM) .The test cases were classified as benign and malignant. FCM was trained by Hebbian Learning algorithm and it attained an accuracy of 90.58% for normal cases and 89.47% for abnormal cases.

In this study [78], they developed a deep learning model for classification of patients with tongue cancer based on oral endoscopic images using various convolutional neural network (CNN). The deep learning model developed based on the endoscopic images showed acceptable performance in tongue cancer diagnosis. The data mining techniques such as C 4.5, Random tree, and multilayer perceptron neural network were applied for Oral cancer classification in [79]. The C4.5 algorithm achieved best accuracy for the given datasets compared to other classifiers.

The paper [80] proposed deep learning algorithm for classification of oral images into either normal or abnormal images. The cancer areas were divided into Mild or severe using morphological operations and diagnosed further by using deep learning algorithm. This paper used 160 oral images and the proposed oral cancer detection system using CNN classification approach achieved 99.3% of detection rate.

2.4. Feature Selection Techniques for Oral Cancer

Numerous feature selection algorithms are available such as Principal component analysis, Correlation co-efficient, Pearson correlation etc. The purpose of feature selection is to find an optimal number of features from OC data in order to generate more efficient and compact model for prediction of OC. The research work in [81] used data mining techniques such as classification, clustering to identify potential oral cancer patients. It also used Genetic algorithm for feature selection in OC.

In this article [82], hybrid feature selection was designed by combining mean-shift and Recursive Feature Elimination (RFE) techniques to increase discrimination ability of the feature vectors of Laser Induced Fluorescence data. The algorithms performance was evaluated on in-vivo recorded LIF data set consisting of spectra from normal, malignant and pre-malignant patients. Sensitivity of above 95% and specificity of above 99% towards malignancy are obtained using the proposed method.

The work proposed in [83] combined 3 feature selection algorithms namely CFS, Information gain and Pearson Correlation method for reducing the size of OC data and used KNN , SVM, NN for classification. These methods reduced the number of attributes from 25 to 14and increased the classification accuracy. The aim of the paper [84] was to accurately predict the occurrence of oral cancer using minimum number of attributes by applying PCA method followed by enhanced-support vector machine (E-SVM) for oral cancer detection and identification in medical sectors. PCA method cut down the attributes of OC data from 25 to 10 only.

A pair wise integration of data pre- processing and hybrid feature selection was proposed in [85] for imbalanced OC data.

JOURNAL OF ALGEBRAIC STATISTICS
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The use of resampling strategies for imbalanced data set achieved higher accuracy than without resampling. The validation results of AdaBoost showed that all classification algorithms have an improved accuracy when implemented with SMOTE-RUS resampling technique rather than boosting algorithm.

III. HIGHLIGHTS

- AI is more accurate in analysing and predicting oral cancer as compared to the traditional method of diagnosis. Moreover, most of the AI algorithms exhibited precise results in predicting the OC occurrence.
- From this survey, we observed that the machine learning techniques and materials used previously are mainly focused on identifying Oral Cancer presence, classification of cancer types. Most of the research works concentrated on the comparison of various machine learning algorithms for cancer prediction. Hence, staging of oral cancer is significant task in the oral cancer prognosis and diagnosis.
- This work is not done by any researcher, which is a most required task in examining prognosis as well as treatment of cancer patient for medical practitioner.
- Most of the deep learning models provided a reliable and effective solution to deal with challenging diseases like OC.
- Thus, current study invokes on applying various supervised machine learning methods especially deep hybrid learning methods for analysing efficient staging in oral cancer development.

IV. CONCLUSION

The main objective of this paper is provide a systematic review on using Artificial, ML and deep learning techniques in medical field especially for Oral cancer detection and prediction. In this paper, some AI, machine learning and deep learning classification models for oral cancer detection have been discussed. Many studies showed that Machine learning models have promising performances for diagnostic and prognostic analyses of oral cancer. These models should be improved to enhance interpretability, and externally validated for generalizability in order to be integrated into daily clinical practices using deep hybrid learning techniques.

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