Co-relation of Oral Cancer with Deep Learning : A Systematic Review

ABSTRACT

This document compiles reviews of diverse research efforts and methodologies addressing oral cancer detection, diagnosis, and prevention, with a focus on artificial intelligence (AI), machine learning (ML), and deep learning (DL). The studies highlight the pivotal role of advanced computational models in automating diagnostics, improving accuracy, and enabling early detection. Emphasis is placed on applications like Convolutional Neural Networks (CNNs), hybrid AI approaches, and smartphone-based imaging, which show significant promise in detecting oral squamous cell carcinoma (OSCC) and oral potentially malignant disorders (OPMDs). Key findings across studies reveal that DL outperforms traditional diagnostic methods in accuracy and efficiency, particularly in image-based analysis. Challenges such as data scarcity, ethical concerns, and infrastructural barriers persist, suggesting areas for future research. Moreover, region-specific analyses and socioeconomic insights reveal disparities in oral cancer prevalence and diagnostic accessibility, especially in low-resource settings like Southeast Asia and India. The reviews collectively underscore the transformative potential of integrating AI into clinical workflows, enhancing early detection and personalized treatment strategies for oral cancer.

Keywords - Oral cancer, Artificial intelligence, Deep learning, Convolutional Neural Networks, Early diagnosis, Oral squamous cell carcinoma, Machine learning, Detection methodologies, Public health, Healthcare innovation.

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I. INTRODUCTION

Oral cancer is still one of the leading diseases in the world and is ranked at the sixth position in terms of incidence of cancer. It is more prevalent in areas of high tobacco consumption and poor health care, including South and Southeast Asia, where other tobacco, risk alcohol, factors and including HPV the infections use are of prevalent. smokeless Even though there have been recent developments in the medical field, the diagnosis of oral cancer remains difficult and many presentations are made at advanced stages thereby reducing the survival rates and leading to high mortality.

The enhanced utilization of artificial intelligence (AI) and machine learning (ML) has created possibilities for changes in the prevention, diagnosis and management of oral cancer. These technologies have the capability of transforming the complex diagnostic processes, increase the level of accuracy and decrease for the highly need trained personnel. State-of-the-art DL models such as Convolutional Neural Networks (CNNs) have been able to deliver high levels of performance in image analysis, lesion detection and malignancy prediction. Such tools are crucial in mitigating the inequalities in the healthcare system as they provide alternatives that are easily implementable and less expensive especially in areas with limited resources.

The present study reviewed the literature published during the last two decades to identify the potential of AI in enhancing the diagnostic workflows. Some of the techniques that have been used (3DCNNs) include and 3D the convolutional combination neural of networks ML with the traditional methods and have been found to increase the sensitivity and specificity of detecting OSCC and OPMDs. Such models are capable of identifying the vital characteristics from histopathological images, radiographs and even the clinical photographs taken by a smartphone, thus making them more inclusive.

In parallel, smokeless tobacco (SLT) use, a critical risk factor for oral cancer, remains a global public health challenge. Systematic reviews have emphasized the higher odds of oral malignancy among SLT users, particularly in Southeast Asia, where products like gutkha and pan carry the highest risks. Understanding the epidemiology and region-specific factors of oral cancer can inform targeted AI-based interventions, integrating prevention with early detection.

The integration of AI in healthcare is not without challenges. Limited access to high-quality datasets, the need for extensive computational resources, and ethical concerns about patient data privacy hinder the widespread adoption of these technologies. Additionally, the variability in oral lesion presentations, imaging modalities, and dataset imbalances underscore the need for standardization and collaboration across research institutions.

This paper explores the intersection of AI technologies and oral cancer diagnostics, providing a systematic review of the current advancements, challenges, and future prospects. It emphasizes the critical need for multidisciplinary approaches that combine technological innovation with public health strategies to enhance global oral cancer outcomes. By leveraging AI's capabilities, clinicians can achieve earlier and more accurate diagnoses, potentially improving survival rates and reducing the global burden of this disease.

II. REVIEW

The review titled "**Association of Smokeless Tobacco Use and Oral Cancer: A Systematic Global Review and Meta-Analysis**" by Smita Asthana, Satyanarayana Labani, Uma Kailash, Dhirendra N Sinha, Ravi Mehrotra published in 2019[1] assesses the global link between smokeless tobacco (SLT) use and oral cancer, addressing gaps in geographical and product-specific data.

Aim: To assess the risk of oral cavity malignancy among smokeless tobacco users who have ever utilized SLT products, in comparison to those who have never come across such products.
Methods: The study in the paper, based on 37 research publications focused on case-control and cohort studies covering the time span of 1960 to 2016, set in four WHO regions; Eastern Mediterranean, Europe, the Americas and Southeast Asia. The random-effects models were used to compute the odds ratios (ORs) for various subgroups, which included SLT and the gender, the region and the types of SLT.
Findings: The use of SLT greatly increases the chances of developing oral cancer especially in Southeast Asia (SEAR OR=4.44) and more rare in the Eastern Mediterranean region (EMR OR=1.28). Women face a much higher risk than men (OR = 5.83) while the risk for the men is (OR = 2.72). The odds for pan tobacco chewers to develop oral cancer are the highest followed by gutkha users (OR = 7.18) while a product such as snus, which is non-chewing tobacco, had a lower association with oral cancer (OR = 0.86).
Conclusions: SLT is a significant risk factor for oral cancer with regional and product-specific differences, highlighting the need for stricter public health regulations and cessation measures, particularly in high-risk areas like SEAR. Further research is recommended to explore genetic, hormonal, and environmental risk factors in women and regional variations. This meta-analysis underscores the importance of addressing SLT use alongside smoking in cancer prevention initiatives, providing valuable insights for policymakers.

The paper, "**An Early Diagnosis of Oral Cancer Based on Three-Dimensional Convolutional Neural Networks**" by S. Xu et al. Published in 2019[2], explores the use of advanced deep learning techniques for the early detection of oral cancer. Key points include:

Goal: The study examines the effectiveness of 3D convolutional neural networks (3DCNNs) in analyzing oral CT images in an effort to assist in differentiating between benign and malignancy oral cancers. It places emphasis on the contrast between the efficacy of the 3DCNN and recent 2DCNN architectures in describing the same problem.
Methodology: Both 2D and 3D CNNs were constructed with comparable hierarchical structures to classify oral tumors.Data was sourced from approximately 7,000 CT images of oral cancers, spanning 20 years. Techniques like data augmentation (rotation, scaling, translation, etc.) were applied to address small sample sizes and imbalance in the dataset.Dynamic contrast-enhanced CT (DCE-CT) images were used to calculate enhancement rates, capturing the dynamic characteristics of lesions.
Results:3DCNN vs. 2DCNN: The 3DCNN model outperformed the 2DCNN, achieving a 9% higher AUC (Area Under the Curve) value and approximately 10% improved sensitivity.
Dynamic Enhancement Imaging: 3DCNNs using enhancement rate images significantly improved diagnostic accuracy and sensitivity over single-sequence images. The AUC for the 3DCNN on enhancement rate images was 0.801, a 5% improvement over single-

sequence analysis.The inclusion of three-dimensional spatial and dynamic features allowed 3DCNNs to better capture tumor characteristics.
Conclusion:3DCNNs are more effective than 2DCNNs in diagnosing oral cancers early by leveraging three-dimensional spatial and dynamic information.The findings suggest a significant potential for 3DCNNs in enhancing CT-assisted diagnosis systems, aiding in the early and more accurate detection of oral cancers.

This research highlights the advancements in AI-driven medical imaging and supports the integration of 3DCNNs into diagnostic tools for improved cancer detection.

In the paper"**Oral Cancer Diagnosis and Perspectives in India**" by Vivek Borse, Aditya Narayan Konwar, Pronamika Buragohain published in 2020[3] the challenges risk elements and advancements in identifying oral cancer in the Indian setting are explored. Key points include

Overview of Oral Cancer in India: Globally oral cancer ranks as the sixth most common type of cancer. In the vast landscape of India almost a third of these cases find their roots. The leading causes that push the numbers up are tobacco usage whether one smokes it or chews it betel quid indulgence drinking alcohol not taking care of one's mouth properly and catching viruses like HPV. In many situations around 60 to 80 percent of the time people find out they have the condition when it's already pretty far along. This leads to higher chances of not making it and only about 20 percent manage to live beyond five years.
Diagnostic Techniques: Traditional ways to figure out what's wrong with someone usually involve checking them over physically, taking tiny pieces of their body to look at under a microscope (that's what biopsies are), using machines to get pictures of the inside of their body (think of CT, MRI, and PET scans), and examining the structure of tissues to spot diseases. On the new front, doctors are now looking into methods like using light to get detailed images of tissues (that's what optical coherence tomography does), shining lasers to study the chemical makeup of cells (which is what Raman spectroscopy is all about), and checking for disease markers in the blood or using special staining techniques to see if someone's sick. Researchers have also come up with new kinds of tiny tools and smart biosensors. These are designed to catch diseases early on by checking for special signs in saliva.
Regional and Socioeconomic Insights: Differences based on location are clear; for example states such as West Bengal face more cases than Kerala does. When it comes to wealth and schooling levels people with less money and education often face more health challenges and worse results.
Challenges and Future Directions: In India today the way doctors figure out what's wrong with someone usually involves methods that take a lot of time are expensive and require the kind of doctors who are hard to find. It's really important now to come up with ways to check for health problems that don't cost much are easy for anyone to use and don't involve going inside a person's body. Efforts to raise public awareness along with steps to cut down on the use of tobacco and betel quid play a crucial role.
The review shines a light on how important it is for new tech to be used and for better public health plans to be put in place to tackle the big problem of mouth cancer in India.

This paper by Kavyashree C., H.S. Vimala, Shreyas J. published in 2024[4] is a systematic review of artificial intelligence (AI) techniques used for the detection of oral cancer. Its main objectives include summarizing existing AI methodologies, evaluating their effectiveness, and highlighting their advantages and limitations. Below is a summary of its key points:

Methodology: The paper reviews 73 articles published between 2014 and 2023.The articles primarily focus on machine learning, deep learning, fuzzy computing, data mining, and genetic algorithms for oral cancer detection.The analysis considers input sources such as histopathological images, MRI, CT scans, and genetic datasets.
Key Techniques and Findings
Machine Learning (ML):Widely used classifiers include Support Vector Machines (SVM), Random Forest, and Decision Trees.ML algorithms achieve high detection accuracy (>90%) but require extensive preprocessing and domain expertise for labeled datasets.
Deep Learning (DL):Convolutional Neural Networks (CNNs) dominate the field, excelling in segmentation, feature extraction, and classification.Techniques like transfer learning and ensemble models enhance accuracy, often exceeding 95%.Challenges include high computational cost and the need for large datasets.
Data Mining:Focuses on analyzing patterns in large datasets to assist in diagnosis and prevention.Algorithms like Artificial Neural Networks (ANNs) and decision trees are common.
Effective in risk assessment and preventive measures.
Challenges and Opportunities
Challenges:
- Limited access to high-quality datasets.
- High computational requirements for deep learning models.
- Need for standardized evaluation metrics.

Opportunities:
- Integration with cloud computing and IoT for real-time detection.
- Development of cost-effective tools for resource-limited settings.
- Collaborative datasets for improved model generalization.

Conclusion
The study emphasizes the transformative potential of AI in oral cancer detection. While deep learning techniques show the highest promise, integrating different AI methods and addressing current limitations can further enhance diagnostic accuracy and accessibility.

The paper **"Artificial intelligence in early diagnosis and prevention of oral cancer"** by Shruthi Hegde, Vidya Ajila, Wei Zhu, Canhui Zeng published in 2022[5] explores the potential applications of artificial intelligence (AI) in improving the early detection, prevention, and management of oral cancer (OC). Below is a summary:
Introduction

- **Problem Statement**: Oral cancer (OC), particularly oral squamous cell carcinoma (OSCC), is a significant global health issue, with late diagnosis leading to high morbidity and mortality rates.
- Early detection increases survival rates to 75–90%, emphasizing the need for timely diagnosis and management.
- AI has emerged as a transformative technology capable of analyzing large datasets and assisting clinicians in screening, diagnosis, and treatment.

Methods

- The study followed PRISMA guidelines and conducted a literature review using PubMed and Scopus databases (2012–2022).
- AI's applications in OC screening, diagnosis, prediction, and management were examined.

Applications of AI

1. **Screening and Early Detection**:
    - AI systems, such as convolutional neural networks (CNNs) and deep learning algorithms, have been used to classify lesions as benign or malignant with high accuracy.
    - Tools like DenseNet-121 and faster R-CNN have been developed for automated detection from clinical photographs and smartphone-based probes, enabling access in remote regions.
2. **Imaging Techniques**:
    - **Optical Coherence Tomography (OCT)**:
        - AI-enhanced OCT systems improve diagnostic accuracy, overcoming user training limitations.
    - **Radiographic Imaging**:
        - Contrast-enhanced CT (CECT) and MRI integrated with AI assist in tumor evaluation, lymph node metastasis prediction, and surgical planning.
    - Histopathology and cytology images analyzed by AI enhance diagnostic precision compared to manual methods.
3. **Prediction and Prognosis**:
    - AI models predict malignant transformation of oral potentially malignant disorders (OPMDs) and disease recurrence.
    - Biomarker analysis using AI aids in assessing cancer risks and survival outcomes.
4. **Treatment Planning**:
    - AI supports treatment planning by improving decision-making in areas like radiotherapy dose calculation, segmentation, and intensity-modulated radiotherapy (IMRT).

Advantages of AI in Oral Oncology

- Automates and enhances diagnostic accuracy.
- Facilitates self-examination and remote screening in underserved areas.
- Integrates imaging, clinical data, and biomarkers for comprehensive assessments.
- Assists clinicians with decision-making, reducing diagnostic errors and improving patient outcomes.

Challenges and Limitations

- Limited availability of high-quality datasets and retrospective data collection.
- Ethical and privacy concerns regarding patient data.
- Infrastructure requirements for data storage and model training.
- Imbalances in datasets and lack of integration with clinical and biopsy findings.

Future Directions

- Integration of AI with radiomics to extract advanced tumor features from CT and MRI scans.
- Development of data fusion algorithms combining clinical, histological, and molecular data for improved diagnostic accuracy.
- Conducting multicenter studies with large, diverse datasets to enhance AI performance.

Conclusion

AI shows immense potential in transforming the early detection, prevention, and management of oral cancer. While deep learning methods outperform traditional machine learning techniques, combining AI with traditional approaches and overcoming current challenges can further enhance diagnostic precision and improve global oral cancer care.

The paper **"Role of Artificial Intelligence in the Early Diagnosis of Oral Cancer: A Scoping Review"** by García-Pola M, Pons-Fuster E, Suárez-Fernández C, Seoane-Romero J, Romero-Méndez A, López-Jornet P published in 2021[6] explores the potential of artificial intelligence (AI) in improving the early, non-invasive diagnosis of oral cancer. Below is a concise summary:

Introduction

- Oral cancer is associated with high mortality rates due to late-stage diagnosis.
- Early detection, particularly of oral potentially malignant disorders (OPMDs), is crucial for effective treatment.
- AI, through machine learning (ML) and deep learning (DL), can process large datasets and enhance early diagnosis and decision-making.

Methods

- The scoping review followed PRISMA guidelines and analyzed studies published from 2000–2020 using databases like PubMed and Web of Science.
- Inclusion criteria focused on non-invasive diagnostic techniques, while studies on radiological imaging, metastasis, or animal experimentation were excluded.
- Thirty-six studies met the criteria.

Key Findings

1. **Applications of AI in Early Detection**:
    - AI is used to classify lesions as benign, malignant, or potentially malignant through medical images, fluorescence imaging, exfoliative cytology, and predictive models.
2. **Non-invasive Techniques**:
    - **Mobile Phone Imaging**:

        - Smartphones equipped with autofluorescence imaging and neural networks showed promising results in classifying lesions and guiding referrals.
        - Sensitivity ranged between 85% and 93%, with high specificity for some applications.
    - **Medical Imaging**:
        - Tools like CNNs (Convolutional Neural Networks) improved lesion classification accuracy, reaching up to 97% in some studies.
    - **Fluorescence Imaging**:
        - Enhanced lesion visualization and detection, especially with tools like VELscope, improving diagnostic accuracy.
    - **Exfoliative Cytology**:
        - AI models, such as support vector machines (SVM), classified oral cancer and precancerous cells with sensitivities and specificities nearing 100%.
3. **AI in Predictive Modeling**:
    - AI models were used to predict the risk of OPMD transformation and oral cancer development, achieving high accuracy and precision.
4. **Challenges**:
    - Variability in datasets, risk of bias, and lack of standardization hinder the large-scale adoption of AI.
    - Ethical and privacy concerns, as well as infrastructure demands, remain significant obstacles.

Conclusion

AI has the potential to revolutionize early oral cancer detection by integrating non-invasive diagnostic methods and predictive models. However, standardization of methodologies, improved datasets, and ethical frameworks are essential for widespread implementation. Future research should focus on combining AI with traditional diagnostic methods for better outcomes.

The paper by Mira, E. S., Sapri, A. M. S., Aljehanı, R. F., Jambı, B. S., Bashir, T., El-Kenawy, E. S. M., & Saber, M. published in 2024[7] focuses on the **early diagnosis of oral cancer** using smartphone-based image processing and deep learning techniques. Here's a summary of its key points:

Objectives

- Improve oral cancer diagnostic accuracy using handheld smartphone cameras.
- Leverage deep learning to classify oral lesions captured in smartphone images.
- Provide a cost-effective and accessible diagnostic tool, particularly for low-resource settings.

Methodology

- **Data Collection**:
    - Images were captured using smartphone cameras with a centered rule method to ensure high-quality lesion-focused images.
    - A dataset of 232 patients was compiled, categorized into five classes: normal mucosa, aphthous ulcers, low-risk OPMDs (Oral Potentially Malignant Disorders), high-risk OPMDs, and oral cancer.
- **Image Preprocessing**:
    - Images were centered and cropped to highlight lesions.
    - A resampling technique was introduced to handle class imbalances and image variability.
- **Deep Learning**:
    - The HRNet-W18 network was fine-tuned using the ImageNet pre-trained model to classify the oral images.
    - Data augmentation techniques such as rotation, resizing, and normalization were applied.

Results

- The proposed method achieved:
    - **Sensitivity**: 83.0%
    - **Specificity**: 96.6%
    - **Accuracy**: 84.3%
    - **F1 Score**: 83.6%
- The resampling method improved the F1 score by 6%, while centered image positioning enhanced performance by 8% compared to random positioning.
- HRNet-W18 outperformed other models like VGG16 and DenseNet169 in accuracy and efficiency.

Key Contributions

- Introduced a robust method for image collection and preprocessing using smartphone cameras.
- Demonstrated the feasibility of deep learning for oral cancer detection using affordable, accessible tools.
- Highlighted the potential of AI in early diagnosis, reducing diagnostic workload and improving patient outcomes.

Limitations & Future Work

- Only five categories of oral lesions were analyzed; expanding this is necessary for broader applicability.
- Validation on other smartphone models and diverse patient groups is required.
- Further refinement in distinguishing between high-risk OPMDs and cancerous lesions is suggested.

Conclusion

The study proposes a promising and practical approach for early oral cancer detection using smartphone images, which could greatly benefit areas with limited access to healthcare resources.

This paper Khanagar SB, Alkadi L, Alghilan MA, Kalagi S, Awawdeh M, Bijai LK, Vishwanathaiah S, Aldhebaib A, Singh OG published in 2023[8] systematically reviews the use of artificial intelligence (AI) models in diagnosing, classifying, and predicting oral cancer (OC) using histopathological images. Key aspects of the study include:

Objectives

- Evaluate AI's effectiveness in diagnosing and predicting oral cancer.

- Assess AI's ability to differentiate normal from malignant regions, predict patient survival, and grade cancer severity.

Methodology

- A systematic search (2000–2023) of databases such as PubMed, Scopus, and Cochrane identified 19 studies meeting inclusion criteria.
- AI algorithms analyzed included convolutional neural networks (CNNs), capsule networks, and hybrid models.

Findings

- **Diagnostic Accuracy**:
  - AI models achieved high accuracy (89.47%-100%) in detecting oral squamous cell carcinoma (OSCC).
  - Techniques like CNNs and hybrid methods were especially effective for early and accurate diagnosis.
- **Classification**:
  - AI differentiated normal and malignant tissues with sensitivity (97.76%-99.26%) and specificity (92%-99.42%).
  - Deep learning models showed superior performance compared to manual approaches.
- **Prediction**:
  - AI-based histomorphometric analysis improved survival prediction by identifying high-risk patients more accurately than traditional methods.
- **Grading Cancer Severity**:
  - Automated grading of tumors using histopathological features provided accuracy up to 90.58% for low-grade tumors and 89.47% for high-grade tumors.

Key Contributions

- Demonstrates AI's potential to complement pathologists, improving diagnostic speed and accuracy.
- Highlights AI's value in resource-limited settings by providing consistent and automated analysis.

Limitations

- Most models were trained on limited datasets, potentially affecting generalizability.
- Challenges with AI model interpretability and acceptance in clinical practice.

Conclusion

AI significantly enhances oral cancer diagnosis and prognosis, outperforming many traditional methods. Future advancements should focus on larger datasets, model transparency, and clinical integration. Regulatory support is essential for widespread adoption.

This research by I. U. Haq, M. Ahmed, M. Assam, Y. Y. Ghadi and A. Algarni published in 2023[9] explores advanced AI-based techniques to enhance the diagnosis of Oral Squamous Cell Carcinoma (OSCC) through histopathological image analysis. The study introduces and evaluates three innovative hybrid methodologies, combining traditional and deep learning approaches for feature extraction and classification.

Objectives

- Improve the diagnostic accuracy and efficiency of OSCC detection.
- Develop AI-powered methods to reduce diagnostic errors and accelerate decision-making.

Methodologies

Three approaches were tested:

1. **Gabor Filter + CatBoost**:
   - Used Gabor filters to extract texture-based features and classified them with the CatBoost algorithm.
   - Achieved an accuracy of 69% but struggled with sensitivity and precision.
2. **ResNet50 + CatBoost**:
   - Extracted high-level features from ResNet50, a deep learning model, followed by PCA (Principal Component Analysis) for dimensionality reduction and classification using CatBoost.
   - Improved accuracy to 93%, showcasing better feature representation and classification performance.
3. **Gabor + ResNet50 + CatBoost (Hybrid)**:
   - Combined texture features from Gabor filters with high-level patterns from ResNet50, yielding a hybrid feature set classified with CatBoost.
   - Delivered the highest performance with:
     - Accuracy: **94.92%**
     - Precision: **95.51%**
     - Sensitivity: **94.30%**
     - Specificity: **95.54%**
     - F1 Score: **94.90%**

Key Findings

- The hybrid method outperformed individual approaches, demonstrating the synergy between traditional image processing (Gabor filters) and deep learning (ResNet50).
- The CatBoost classifier provided robust classification capabilities, particularly with hybrid features.
- Hybrid approaches showed potential to enhance diagnostic accuracy while reducing computational complexity.

Dataset

- Utilized 5,192 histopathological images (2,494 normal and 2,698 OSCC).
- Data was split into training (75%), validation (13%), and testing (12%).

Conclusions

- The hybrid method combining Gabor filters and ResNet50 with CatBoost achieved the best results for early OSCC detection.
- These AI-based systems can assist pathologists in diagnosing OSCC more accurately and quickly, reducing the manual workload and improving patient outcomes.
- Future research should validate the methods on larger, more diverse datasets and explore their integration into clinical practice.

Implications
The study highlights the transformative potential of AI in cancer diagnostics, emphasizing its role in early detection and efficient treatment planning, especially in resource-constrained settings.

The paper, ″**Early Diagnosis of Oral Squamous Cell Carcinoma (OSCC) Based on Histopathological Images Using Deep and Hybrid Learning Approaches**″ by Fati SM, Senan EM, Javed Y published in 2022[10] , explores AI-based methodologies for diagnosing OSCC. It proposes hybrid approaches combining deep learning (CNN models such as AlexNet and ResNet-18) with machine learning (SVM and ANN). The paper aims to enhance diagnostic accuracy and speed by overcoming challenges in manual histological analysis.
Key Contributions:
1. **Hybrid Techniques**:
    - *CNN-SVM*: Combines CNN feature extraction with SVM classification.
    - *Hybrid Features with ANN*: Merges features from CNN models and traditional algorithms (e.g., DWT, LBP, FCH, and GLCM) for ANN-based classification.
2. **Data Processing**:
    - The dataset includes 5,192 histopathological images (48% normal and 52% malignant).
    - Images undergo preprocessing (artifact removal, noise reduction) and feature extraction for enhanced diagnostic accuracy.
3. **Results**:
    - The hybrid CNN-SVM approach achieved up to 98.1% accuracy.
    - The hybrid feature-based ANN approach reached an accuracy of 99.3%, with high specificity (99.42%), sensitivity (99.26%), and AUC (99.39%).

Importance:
The study demonstrates that integrating deep learning with hybrid feature extraction significantly improves OSCC diagnosis using histopathological images, paving the way for faster, more accurate medical assessments.

The paper, ″Application of Artificial Intelligence and Machine Learning for Prediction of Oral Cancer Risk" by Alhazmi, A., Alhazmi, Y., Makrami, A., Masmali, A., Salawi, N., Masmali, K., & Patil, S. published in 2021[11] explores the use of artificial neural networks (ANNs) to predict the risk of developing oral cancer (OC) based on patient data, including risk factors, systemic medical conditions, and clinicopathological features.
Key Points:
1. **Objective**:
    - Develop an ANN-based model to predict oral cancer risk effectively and assist in early screening and diagnosis.
2. **Methods**:
    - A dataset of 73 cases (22 benign and 51 malignant) was used, with 29 variables such as patient demographics, clinical presentations, and lifestyle habits.
    - The dataset was split into training (75%) and testing (25%) sets.
    - The ANN model included an input layer (29 variables), a hidden layer, and an output layer with binary classification (benign or malignant).
    - Model performance was assessed using 10-fold cross-validation to ensure generalizability.
3. **Results**:
    - The ANN achieved an average sensitivity of 85.71% and specificity of 60.00%.
    - The overall accuracy was 78.95%.
    - The study highlighted the ANN model's potential to estimate malignancy probability and aid in oral cancer screening.
4. **Conclusions**:
    - The ANN model demonstrated its usefulness in predicting OC risk, although the specificity was moderate.
    - The authors recommend future studies with larger, more diverse datasets to enhance the model's robustness and include additional machine learning techniques like Random Forest and Support Vector Machines.

Importance:
This study underscores the potential of AI and machine learning, particularly ANNs, in improving the early detection and diagnosis of oral cancer, which is critical for better patient outcomes.

The paper, ″A Novel Lightweight Deep Convolutional Neural Network for Early Detection of Oral Cancer" by Jubair, F., Al-karadsheh, O., Malamos, D., Al Mahdi, S., Saad, Y., & Hassona, Y. published in 2021[12] introduces an efficient artificial intelligence-based approach for detecting oral cancer and potentially malignant disorders (OPMDs) using standard clinical images.
Objective:
- Develop a lightweight convolutional neural network (CNN) model for binary classification of oral lesions (benign vs. malignant or potentially malignant).

Methods:
- A dataset of 716 clinical images was utilized, comprising 33% "suspicious" lesions (oral squamous cell carcinoma or epithelial dysplasia) and 67% benign lesions.
- The EfficientNet-B0 model was chosen for its lightweight and efficient architecture, which uses transfer learning to optimize performance on small datasets.
- The model architecture included input, pooling, convolutional, and fully connected layers, along with weighted cross-entropy loss to mitigate the effects of class imbalance.

Performance:
- Accuracy: 85.0% (95% CI: 81.0–90.0%)

- Sensitivity: 86.7% (95% CI: 80.4–93.3%)
- Specificity: 84.5% (95% CI: 78.9–91.5%)
- AUC: 0.928, indicating strong model performance in distinguishing between classes.

Significance:

- The model demonstrated comparable performance to traditional, more resource-intensive CNNs like VGG19 and ResNet101.
- Its lightweight design makes it suitable for deployment on low-computation devices, such as smartphones, enabling a practical, cost-effective tool for early detection in resource-limited settings.

Limitations and Future Directions:

- The dataset focused solely on tongue lesions, necessitating further studies for other anatomical sites.
- The relatively small dataset, while larger than in some previous studies, highlights the need for international collaboration to build expansive datasets.
- Future work could extend the model to multiclass classification or integrate additional AI techniques for improved performance.

Conclusion:
The study demonstrates that lightweight CNNs like EfficientNet-B0 can provide effective, accessible solutions for early oral cancer detection, supporting clinical decision-making and potentially reducing morbidity and mortality associated with late diagnoses.

The paper titled "A Current Review of Machine Learning and Deep Learning Models in Oral Cancer Diagnosis" by Dixit, S., Kumar, A., & Srinivasan, K. published in 2023[13] reviews recent advancements, applications, and challenges in using AI-based technologies for oral cancer (OC) diagnosis. Below is a summary of the key points:

1. Introduction

- Oral cancer, the sixth most common cancer worldwide, has high prevalence in regions like South and Southeast Asia.
- Major risk factors include tobacco use, alcohol consumption, HPV infection, and poor diet.
- Early detection significantly improves survival rates, but late-stage diagnosis remains a challenge.

2. Role of AI in OC Diagnosis

- AI, particularly machine learning (ML) and deep learning (DL), is instrumental in analyzing large datasets from imaging and clinical sources.
- AI methods improve diagnostic precision and treatment planning by automating complex image analyses and detecting early cancerous changes.

3. Technologies for Diagnosis

The paper discusses advanced diagnostic methods, including:

- **Visual staining**: Affordable techniques like toluidine blue staining to detect lesions.
- **Cytological methods**: Exfoliative cytology to study oral epithelial cells.
- **Optical imaging**: Light-based methods for identifying mucosal changes.
- **Saliva-based diagnostics**: Analyzing biomarkers in saliva for non-invasive detection.
- **Tomography and fluorescence imaging**: Advanced imaging methods enhanced by AI models.
- **Lab-on-chip systems**: Miniaturized devices for real-time analysis of biomarkers.

4. AI and ML Models

The study categorizes AI applications into ML and DL models:

- **ML Models**: Techniques such as Support Vector Machines (SVM), Decision Trees (DT), Random Forests (RF), and K-Nearest Neighbors (KNN) have been used for classification and prediction tasks. These models perform well in specific diagnostic applications but are limited by data quality and interpretability.
- **DL Models**: Deep Neural Networks (DNNs), Convolutional Neural Networks (CNNs), and ensemble learning approaches are highly effective in image analysis, enabling automated lesion detection with minimal human intervention.

5. Challenges and Future Directions

- Data limitations: A lack of diverse, high-quality datasets affects model training and generalizability.
- Interpretability: Complex models, especially in DL, require better transparency for clinical adoption.
- Integration: Bridging AI tools with existing healthcare systems and ensuring regulatory compliance is essential.
- Ethical considerations: Addressing privacy and biases in AI applications is necessary for widespread use.

6. Conclusion

The paper highlights the transformative potential of ML and DL in OC diagnosis, emphasizing their ability to assist in early detection and improve treatment outcomes. It advocates for multidisciplinary research, enhanced data collection, and the development of accessible, low-cost diagnostic tools.

The paper titled **"A Comprehensive Assessment of Convolutional Neural Networks for Skin and Oral Cancer Detection Using Medical Images"** by Dhatri Raval, Jaimin N. Undavia published in 2023[14] evaluates the application of Convolutional Neural Networks (CNNs) in detecting skin and oral cancers through medical imaging. Here's a summary of the key points:

1. Introduction

- Skin and oral cancers are major global health issues with high prevalence and mortality rates.
- Traditional diagnostic methods, though effective, are time-consuming and prone to subjectivity.
- CNNs, a deep learning approach, have shown promise in automating the detection and classification of cancer using medical images.

2. CNN Models Studied

The study reviews and compares multiple CNN architectures:

- **AlexNet**: A pioneering CNN architecture.
- **VGGNet**: Known for deeper networks with small filter sizes.
- **ResNet**: Employs residual connections to avoid the vanishing gradient problem.

- **DenseNet**: Features dense connections for efficient feature reuse and reduced parameters.

3. Datasets and Preprocessing
- Datasets include ISIC, PAD-UFES-20, and others with thousands of skin lesion images and a smaller dataset for oral cancer.
- Preprocessing steps include image resizing, augmentation (rotation, scaling, etc.), filtering (e.g., hair removal), and segmentation to improve image quality and dataset robustness.

4. Implementation Details
- **Training**: Models were trained on resized images with augmented datasets to overcome data scarcity and improve generalization.
- **Hyperparameters**: Batch size, learning rate, and activation functions were optimized for better performance.
- **Metrics**: Models were evaluated based on training/validation accuracy and loss.

5. Results
- DenseNet achieved the best performance on skin cancer datasets, owing to its ability to effectively reuse features and reduce computational overhead.
- AlexNet and VGGNet showed decent performance but were less efficient than ResNet and DenseNet in handling complex patterns.
- Challenges in oral cancer detection persist due to limited datasets.

6. Conclusion
- CNNs demonstrate significant potential in improving the accuracy and efficiency of skin and oral cancer detection.
- Larger and more diverse datasets, combined with further advancements in model architectures, are essential for improving results, particularly for oral cancer detection.

The paper highlights the transformative role of CNNs in medical imaging and calls for continued innovation and data availability to enhance diagnostic capabilities.

The paper titled **"Deep Learning in Oral Cancer: A Systematic Review"** by Warin, K., & Suebnukarn, S. published in 2024[15] explores the role and impact of deep learning (DL) applications in the diagnosis and prognostic prediction of oral cancer. Here is a summary:

Background
- Oral cancer is a serious global health issue, with high mortality rates often due to late detection.
- The most common type, oral squamous cell carcinoma (OSCC), is frequently preceded by oral potentially malignant disorders (OPMDs).
- Early diagnosis is critical to improving survival rates.

Objectives
- To systematically review studies applying DL to oral cancer diagnosis and prognosis.
- To evaluate the performance of these models in improving clinical decision-making.

Methodology
- A systematic review was conducted following PRISMA guidelines.
- Databases like PubMed, Scopus, and Google Scholar were searched for studies between January 2000 and June 2023.
- The review included studies that employed DL algorithms for classification, detection, segmentation, and prognostic prediction tasks.

Results
- 54 studies were included: 51 focused on diagnosis and 3 on prognosis.
- DL models demonstrated strong performance:
  - Accuracy ranged from 85% to 100%.
  - F1-scores were between 79.31% and 89.0%.
  - Dice coefficient (for segmentation tasks) was 76.0% to 96.3%.
  - Prognostic prediction was supported by concordance indices between 0.78 and 0.95.
- Studies utilized a variety of imaging modalities, including histopathology, CT scans, and clinical oral images.
- The majority of studies (37 out of 54) were conducted in Asia.

Challenges
- Limited datasets, particularly for OPMDs, hindered model generalization.
- Lack of standardization in model architectures and performance metrics.
- Ethical and interpretability issues remain obstacles to clinical adoption.

Conclusion
- DL models show high diagnostic accuracy and potential utility in clinical settings.
- Future research should address data limitations, model transparency, and integration into healthcare workflows. Collaboration between AI experts and clinicians is vital to advance the field.

This paper emphasizes the promise of DL technologies in transforming oral cancer care while calling for efforts to overcome existing challenges.

The paper titled "Oral Cancer Detection using Machine Learning and Deep Learning Techniques" by Nanditha B.R. and Geetha Kiran A., published in 2022[16], explores the use of machine learning (ML) and deep learning (DL) models for the early detection of oral cancer.

Introduction
Oral cancer, which affects regions such as the lips, oral cavity, nasopharynx, and pharynx, has a significant prevalence, particularly in South Central Asia. Early diagnosis is crucial as it can significantly improve patient outcomes. Traditional diagnostic methods are challenging, so the paper proposes using ML and DL techniques to automate and improve the accuracy of oral cancer detection.

Objective

The primary goal is to develop an automated system for the early detection of potentially malignant oral lesions by creating a large, well-annotated dataset of oral lesions and employing ML and DL models to classify these lesions.

Methods

- **Dataset**: The study uses 630 oral images from various sources, including hospitals. These images were processed to create 1200 lesion images, equally divided between malignant and normal images. Augmentation techniques were applied to increase the dataset size to 9600 images for training purposes.
- **Segmentation**: Lesion regions are extracted from the input RGB images using a combination of color space conversion and region-based active contour segmentation.
- **Feature Extraction**: Features such as GLCM, GLRLM, fractal features, Gabor features, and color features are extracted from the lesion images.
- **Feature Selection**: Irrelevant features are removed using statistical methods like MRMR and Box plot methods, resulting in a set of 19 relevant features.
- **Classification Models**: The study employs several ML models (SVM, KNN, Naive Bayes) and DL models (ANN, CNN). The CNN model, inspired by the VGG-16 network, consists of 43 layers including convolutional, pooling, and fully connected layers.

Results

- **Performance**: Among the ML models, the SVM model performed the best, followed by KNN and Naive Bayes. However, the CNN model outperformed all others with a training accuracy of 99.3% and a testing accuracy of 97.51%.
- **Comparison**: CNN showed superior performance in terms of accuracy, precision, recall, F1 score, and specificity compared to ANN and traditional ML models.

Conclusion

The study concludes that while traditional ML models can effectively classify oral lesions, DL models, particularly CNN, offer superior accuracy and robustness. This indicates that DL techniques hold great promise for automating the detection and classification of oral cancerous lesions.

Future Scope

Future work aims to expand the dataset further and improve model accuracy through advanced techniques in fine-tuning and augmentation. Implementing semantic segmentation could enhance the lesion selection process, potentially leading to even higher accuracy.

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This study demonstrates the potential of integrating ML and DL techniques into medical diagnostics, specifically for oral cancer detection, highlighting the importance of technological advancements in improving healthcare outcomes.

The paper **"Deep Machine Learning for Oral Cancer: From Precise Diagnosis to Precision Medicine"** by Alabi et al. [17]focuses on the application of deep machine learning (DML) techniques in the diagnosis, prognostication, and treatment planning for oral squamous cell carcinoma (OSCC). Below is a summarized overview:

Introduction

- OSCC is a common and aggressive cancer with a high global incidence and often late diagnosis.
- Challenges include suboptimal treatment outcomes and the need for precision medicine.
- Deep learning has emerged as a powerful tool for early detection, improving diagnosis, and supporting precision medicine.

Objective

The study investigates how deep learning can aid in:

1. Precise diagnosis and prognosis of OSCC.
2. Assisting pathologists and clinicians in treatment decisions.
3. Facilitating precision medicine through automated image analysis and predictive modeling.

Methods

- **Systematic Review of Reviews**: The authors analyzed multiple systematic reviews to summarize evidence on deep learning applications in oral cancer.
- **Data Sources**: Data included pathological, radiological, and genomic information.
- **Pipeline for Deep Learning**:
    1. **Image Acquisition and Preprocessing**: High-quality medical images are prepared to remove noise and artifacts.
    2. **Feature Extraction**: Relevant features for diagnosis and prognosis are extracted automatically, reducing reliance on manual interpretation.
    3. **Training and Testing**: Convolutional Neural Networks (CNNs) and other architectures classify the images into categories like malignant or benign.

Findings

1. **Performance Metrics**:
    - Deep learning models achieved high accuracy for OSCC diagnosis:
        - 96.6% for spectra data.
        - 77.89%–97.51% for pathological images.
        - 76.0%–94.2% for radiographic images.
    - These models assist in early detection, precise classification, and prognosis.
2. **Applications**:
    - Identifying lymph node metastasis.
    - Differentiating precancerous and cancerous lesions.
    - Predicting disease-free survival and patient risk stratification.
3. **Advantages**:

- Automation reduces cognitive biases and diagnostic errors.
- Offers cost-effective solutions for early detection, especially in low-resource settings.

Challenges

- Data quality and standardization in medical imaging remain critical issues.
- Deep learning models face challenges in explainability, interpretability, and generalizability.
- External validation with diverse datasets is necessary for clinical adoption.

Conclusion

Deep learning has significant potential in transforming oral cancer management through precision medicine. However, challenges like data standardization and validation must be addressed for widespread adoption.

Future Directions

- Develop standardized guidelines for image acquisition and preprocessing.
- Enhance model interpretability and generalizability.
- Integrate deep learning tools into clinical workflows as support systems for clinicians.

This paper underscores the transformative role of deep learning in advancing personalized care and improving outcomes for oral cancer patients.

The paper titled **"DEEPORCD: Detection of Oral Cancer using Deep Learning"** by R. Dharani and S. Revathy[18] focuses on using deep learning techniques to detect and classify oral cancer from medical images. Below is a summarized overview of the study:

Introduction

- Oral cancer is the eighth most common cancer globally, with significant prevalence in India.
- Traditional diagnostic methods, such as biopsies, have limitations in identifying and classifying cancerous cells.
- The study introduces an automated system using advanced technologies like Convolutional Neural Networks (CNNs) and other machine learning techniques for early detection and classification of oral cancer.

Objectives

1. Develop an automated system for detecting oral cancer using CT scan images.
2. Employ advanced feature extraction, selection, and classification techniques for improved accuracy.
3. Compare the performance of CNN-based methods with other machine learning classifiers.

Proposed Methodology

1. **Preprocessing**:
    - Images are enhanced using histogram equalization (HE) and de-noised using Adaptive Bilateral Filter (ABF).
2. **Segmentation**:
    - The Artificial Bee Colony (ABC) algorithm is used to segment the oral cancer-affected regions.
3. **Feature Extraction**:
    - Three methods—Wavelet Transform, Histogram of Oriented Gradients, and Zernike Moments—are used to extract 140 features (texture, color, and shape).
4. **Feature Selection**:
    - Fuzzy Particle Swarm Optimization (FPSO) is employed to select the most relevant features for classification.
5. **Classification**:
    - CNN is used as the primary classifier. Other methods, such as SVM, K-Nearest Neighbors (KNN), Naive Bayes, and Adaboost, are also compared.

Experimental Results

- **Dataset**: UCI Machine Learning Repository dataset with 1018 oral CT scan images.
- **Performance Metrics**:
    - Sensitivity, Specificity, Accuracy, and Error Rate are used for evaluation.
    - CNN outperformed all other classifiers, achieving an accuracy of 98.2%, sensitivity of 98.45%, and specificity of 98.78%.
    - For segmentation, the ABC algorithm showed superior performance with the highest sensitivity (94.97%) and lowest error rate (5.84%).

Conclusion

- The study demonstrates that CNN-based methods, combined with feature extraction (Wavelet, Zernike Moments) and selection techniques (FPSO), provide highly accurate results for oral cancer detection.
- The ABC algorithm was found to be effective for image segmentation.
- The proposed system shows promise for automated, cost-effective, and accurate oral cancer detection from CT scans.

Future Work

The authors suggest exploring additional datasets and refining the segmentation and classification processes to further enhance the system's accuracy and efficiency.

The paper titled *"Improving Oral Cancer Outcomes with Imaging and Artificial Intelligence"* by Ilhan, B., Lin, K., Guneri, P., & Wilder-Smith, P. published in 2020[19] discusses how integrating imaging technologies and artificial intelligence (AI) can enhance the detection, diagnosis, and treatment outcomes for oral and oropharyngeal squamous cell carcinoma (OPSCC). Below is a summary:

Clinical Need:

- OPSCC is the sixth most common cancer in the U.S., with a high global burden, especially in low- and middle-income countries (LMICs).
- Early detection is crucial as the five-year survival rate significantly decreases from 83% in localized cases to 32% for metastasized cases.

Challenges in Current Practices:

- Dentists, who often serve as the first point of detection, struggle with accuracy due to a lack of training and reliance on subjective assessments.
- Conventional methods, like biopsies, are invasive, resource-intensive, and prone to sampling bias.

Advancements in Imaging:

- Technologies like autofluorescence imaging and optical coherence tomography (OCT) have shown promise but face barriers such as cost, complexity, and user interpretation challenges.
- OCT, in particular, provides near-histological resolution images but has not been widely adopted due to logistical and interpretative issues.

Role of Artificial Intelligence:

- AI, particularly deep learning, improves diagnostic accuracy by analyzing complex imaging data.
- AI-based systems can detect patterns and quantify subtle differences in tissue characteristics that may go unnoticed by humans.

Innovative Applications:

- **Low-Cost Screening**: Smartphone-based probes combined with AI can improve access to high-risk populations, achieving better accuracy than conventional methods.
- **Surgical Assistance**: AI-integrated OCT systems help map tumor margins and heterogeneity intraoperatively, enhancing precision and outcomes.

Barriers and Future Directions:

- Despite technological advancements, clinical adoption is hindered by issues such as cost, ease of use, and integration into workflows.
- Further studies are required to validate these technologies and optimize AI algorithms for practical deployment.

Conclusion:
The paper emphasizes that while imaging and AI have the potential to revolutionize oral cancer care, success depends on addressing logistical barriers, designing user-friendly devices, and tailoring solutions to clinical needs. These advancements could bridge gaps in early detection, improving survival rates and reducing global disparities in cancer care.

The paper titled **"Machine Learning in the Detection of Oral Lesions With Clinical Intraoral Images"** by Dinesh, Y., Ramalingam, K., Ramani, P., & Deepak, R. M. published in 2023[20] explores the application of artificial intelligence, specifically machine learning (ML), for the early detection of oral lesions, including Oral Squamous Cell Carcinoma (OSCC) and Oral Potentially Malignant Disorders (OPMDs), using clinical intraoral images. Below is a summary:

Objective:

- The study aimed to investigate the potential of ML algorithms in identifying oral lesions, including OSCC and OPMDs, from intraoral images to aid early diagnosis and improve patient outcomes.

Methodology:

- A dataset of 360 intraoral images, including healthy oral mucosa, OPMDs, and OSCC cases, was used.
- Roboflow software was employed for image annotation and ML model training.
- Images were categorized based on features like lesion color (e.g., white, red, or mixed) and presentation (e.g., patches or ulcers).
- The ML model was trained on 300 images and tested on 60 images. Results were compared with evaluations by two expert clinicians.

Performance Metrics:

- The ML model demonstrated a specificity of 75% and sensitivity of 88.9% in detecting lesions.
- The agreement between the ML model and expert clinicians was moderate, with a Kappa value of 0.7.
- Precision (correct positive predictions) and recall (ability to detect true positives) were 29.8% and 32.9%, respectively.

Results:

- The ML model effectively identified lesions such as OPMDs and OSCC with performance comparable to that of trained clinicians.
- It showed promise as a diagnostic aid for general dentists and non-specialist healthcare workers.

Discussion:

- ML systems can support the identification of suspicious lesions and aid in referring patients for further diagnostic testing.
- Variability in image resolution and heterogeneity in lesion presentation were limitations that affected accuracy.
- Improvements, including larger datasets and high-resolution imaging, could enhance the model's precision and reliability.

Limitations:

- Use of non-standardized imaging devices (e.g., mobile cameras) resulted in inconsistent image quality.
- The model struggled with distinguishing physiologically altered conditions from pathological lesions.

Future Directions:

- The development of mobile applications integrating ML for lesion detection and referral guidance is planned.
- Expansion of datasets through multicenter collaboration and use of advanced imaging techniques is necessary to improve model performance.

Conclusion:

The study concludes that machine learning-based models, such as those built using Roboflow, have the potential to be reliable tools for the early detection of OPMDs and OSCC. These tools could supplement existing diagnostic methods, particularly in resource-limited settings, improving early detection and enabling timely intervention.

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