



Artificial Intelligence-Assisted Salivary Biomarker Profiling For Early Detection Of Oral Diseases In Children: A Cross-Sectional Analytical Study

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Abstract: Background

Oral diseases remain among the most prevalent chronic conditions affecting children worldwide and continue to represent a significant public health challenge. Early diagnosis is essential for preventing disease progression and reducing long-term morbidity. Saliva has emerged as a promising diagnostic medium because it contains a wide range of proteins, inflammatory mediators, microbial constituents, nucleic acids, and metabolites associated with oral and systemic health. Recent advances in artificial intelligence (AI) and machine-learning technologies have enabled rapid analysis of complex biological datasets, facilitating disease prediction and personalized healthcare. The present study aimed to evaluate the role of AI-assisted salivary biomarker analysis in the early detection of oral diseases among children aged 6–12 years.

Materials and Methods

A cross-sectional analytical study was conducted among 120 children aged 6–12 years. Participants were categorized into healthy and oral disease groups based on clinical findings. Unstimulated saliva samples were collected and analyzed for interleukin-6 (IL-6), matrix metalloproteinase-8 (MMP-8), C-reactive protein (CRP), salivary pH, and Streptococcus mutans counts. Machine-learning algorithms including logistic regression, decision tree analysis, support vector machine, and random forest classification were employed to evaluate biomarker-based disease prediction. Statistical analysis included Student's t-test, Chi-square test, Spearman correlation, and receiver operating characteristic curve analysis.

Results

Children with oral disease demonstrated significantly elevated salivary IL-6, MMP-8, CRP, and Streptococcus mutans levels compared with healthy participants. Salivary pH was significantly lower in the disease group. Among the machine-learning models evaluated, the random forest classifier demonstrated the highest predictive accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve. Significant positive correlations were observed between inflammatory biomarkers and disease severity.

Conclusion

Artificial intelligence-assisted salivary biomarker profiling demonstrated promising potential for early identification of pediatric oral diseases. Integration of salivary diagnostics with machine-learning algorithms may provide a rapid, noninvasive, and cost-effective screening approach in pediatric dentistry.

Clinical Significance

AI-driven salivary diagnostics may facilitate early disease detection, individualized preventive strategies, and improved clinical decision-making in pediatric oral healthcare.

Index Terms - Artificial intelligence, Biomarkers, Early diagnosis, Machine learning, Oral diseases, Pediatric dentistry, Saliva

I. INTRODUCTION

Oral diseases constitute a major global health challenge and affect billions of individuals worldwide, with dental caries remaining the most prevalent noncommunicable disease across all age groups.^{1,2} In children, untreated oral diseases adversely affect mastication, speech, nutrition, growth, school performance, and overall quality of life.³ Despite significant advances in preventive dentistry, early identification of oral diseases remains challenging because pathological alterations often occur at the molecular level before becoming clinically evident.⁴

Dental caries, gingivitis, and early enamel demineralization are among the most common oral diseases affecting pediatric populations.⁵ The Global Oral Health Status Report published by the World Health Organization highlighted that untreated dental caries in primary teeth remains one of the most prevalent health conditions among children worldwide.⁶ Gingival inflammation similarly affects a substantial proportion of school-aged children and may predispose susceptible individuals to future periodontal breakdown.⁷ Consequently, early diagnosis and timely intervention are essential for reducing disease burden and improving oral health outcomes.⁸

Conventional methods for diagnosing oral diseases rely primarily on visual examination, radiographic investigations, microbial culturing techniques, and clinical indices.⁹ Although these approaches remain indispensable in routine practice, they frequently identify disease only after irreversible structural damage has occurred.¹⁰ Radiographic examinations may fail to detect incipient lesions and involve exposure to ionizing radiation.¹¹ Therefore, there is increasing interest in developing noninvasive diagnostic approaches capable of identifying disease during its earliest stages.¹²

Saliva has emerged as an attractive diagnostic biofluid because of its ease of collection, noninvasive nature, cost-effectiveness, and ability to reflect both local and systemic physiological conditions.¹³ Saliva contains numerous proteins, enzymes, cytokines, nucleic acids, metabolites, hormones, antibodies, and microbial products that may serve as indicators of disease activity.¹⁴ Recent advances in salivary diagnostics have resulted in growing recognition of saliva as a valuable medium for disease screening, risk assessment, therapeutic monitoring, and precision healthcare.¹⁵

Among the various salivary biomarkers investigated, inflammatory mediators such as interleukin-6 (IL-6), matrix metalloproteinase-8 (MMP-8), and C-reactive protein (CRP) have demonstrated considerable diagnostic potential.¹⁶ IL-6 is a multifunctional cytokine involved in immune regulation and inflammatory responses and has been associated with gingival inflammation and dental caries activity.¹⁷ MMP-8 plays a critical role in extracellular matrix degradation and periodontal tissue destruction and has emerged as a promising biomarker for inflammatory oral diseases.¹⁸ CRP is an acute-phase protein that reflects inflammatory activity and may contribute to early disease identification.¹⁹

In addition to host-derived biomarkers, microbial biomarkers have attracted considerable attention in pediatric oral disease diagnostics.²⁰ *Streptococcus mutans* remains one of the principal cariogenic microorganisms implicated in the initiation and progression of dental caries.²¹ Elevated salivary levels of *S. mutans* have consistently been associated with increased caries risk and disease activity.²² Furthermore, alterations in salivary pH influence enamel demineralization and microbial colonization and therefore contribute significantly to disease progression.²³

Recent technological developments have revolutionized healthcare diagnostics through the application of artificial intelligence.²⁴ Artificial intelligence encompasses computational methods capable of mimicking human cognitive processes including pattern recognition, predictive analytics, decision-making, and automated data interpretation.²⁵ Machine-learning algorithms can process large multidimensional datasets and identify complex biological relationships that may remain undetected using conventional statistical approaches.²⁶

The integration of artificial intelligence into dentistry has expanded rapidly during the past decade. AI-based systems have demonstrated high diagnostic accuracy in caries detection, radiographic interpretation, periodontal assessment, orthodontic prediction, and oral cancer screening.^{27–29} Several studies have reported diagnostic performances comparable to those achieved by experienced clinicians.³⁰ Consequently, AI has emerged as a promising adjunct for improving diagnostic consistency, efficiency, and clinical decision-making.³¹

The application of artificial intelligence to salivary diagnostics represents an emerging area of considerable interest.³² Salivary biomarker datasets frequently involve numerous variables and complex interactions that

may be difficult to interpret using traditional analytical techniques.³³ Machine-learning algorithms can evaluate multidimensional biomarker profiles, identify predictive signatures, and generate disease-risk models with high diagnostic accuracy.³⁴ Such approaches may facilitate early disease detection, individualized risk assessment, and precision dentistry.³⁵

Recent investigations published between 2021 and 2026 have demonstrated the feasibility of integrating machine-learning techniques with salivary biomarker analysis for identifying periodontal disease, oral potentially malignant disorders, oral cancer, and dental caries.^{36–39} However, evidence regarding the application of AI-assisted salivary biomarker analysis in pediatric oral disease screening remains limited.⁴⁰ The development of reliable, noninvasive, and child-friendly diagnostic approaches is particularly important in pediatric dentistry because children often experience anxiety and reduced cooperation during invasive procedures.⁴¹ Saliva collection is painless, economical, and can be repeated without causing patient discomfort.⁴² When combined with AI-driven predictive analytics, salivary diagnostics may provide clinicians with a powerful tool for early disease detection and preventive intervention.⁴³

Therefore, the present study was undertaken to evaluate the role of artificial intelligence-assisted salivary biomarker profiling in the early detection of oral diseases among children aged 6–12 years. The study also aimed to assess the predictive performance of machine-learning algorithms using salivary inflammatory and microbial biomarkers and determine their potential applicability in pediatric oral healthcare.

II. MATERIALS AND METHODS

Study Design

The present study was designed as a cross-sectional analytical investigation to evaluate the role of artificial intelligence-assisted salivary biomarker profiling in the early detection of oral diseases among children aged 6–12 years. The study was conducted in the Department of Pediatric and Preventive Dentistry over a period of 12 months.

Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from parents or legal guardians before participation. Consent was obtained from participating children wherever applicable.

Study Population

A total of 120 children aged between 6 and 12 years reporting to the outpatient clinic of the Department of Pediatric and Preventive Dentistry were screened for eligibility.

Following clinical examination, participants were categorized into two groups:

Group I (60 Healthy Patients)

Children presenting with:

1. No active dental caries
2. Healthy gingival tissues
3. Absence of enamel demineralization
4. Good oral hygiene status

Group II (60 Oral Disease Patients)

Children presenting with one or more of the following:

1. Active dental caries
2. Gingivitis
3. Early enamel demineralization
4. Poor oral hygiene status

Inclusion Criteria

- a) Children aged 6–12 years.
- b) Apparently healthy children.
- c) Cooperative children willing to participate in the study.
- d) Children whose parents or guardians provided informed consent.

Exclusion Criteria

- a) Children with systemic diseases affecting salivary secretion or composition.
- b) Children receiving antibiotic therapy within the previous three months.
- c) Children receiving anti-inflammatory medications.
- d) Children undergoing orthodontic treatment.
- e) Medically compromised children.
- f) Children with developmental anomalies affecting oral structures.
- g) Children with acute oral infections requiring emergency intervention.

Clinical Examination

Clinical examination was performed under standardized illumination using sterile mouth mirrors and Community Periodontal Index probes.

Dental caries status was assessed using the DMFT/deft index according to World Health Organization criteria. Gingival health was evaluated using the Gingival Index, while oral hygiene status was recorded using the Simplified Oral Hygiene Index (OHI-S).

Early enamel demineralization lesions were identified clinically based on the presence of white spot lesions and loss of enamel translucency. All examinations were performed by a single calibrated examiner to eliminate inter-examiner variability.

Salivary Sample Collection

Unstimulated whole saliva samples were collected between 9:00 AM and 11:00 AM to minimize circadian variations.

Participants were instructed to avoid eating, drinking, chewing gum, or performing oral hygiene procedures for at least one hour before sample collection.

Each child was seated comfortably in an upright position and asked to rinse the mouth thoroughly with distilled water. Approximately 5 mL of unstimulated saliva was collected using the passive drooling technique into sterile polypropylene tubes.

Immediately after collection, samples were transported under cold-chain conditions and centrifuged at 3000 rpm for 15 minutes to remove cellular debris. The supernatant was separated and stored at -80°C until further analysis.

Salivary Biomarker Estimation

The present study evaluated inflammatory, microbial, and physicochemical salivary biomarkers associated with oral disease activity.

Estimation of Interleukin-6 (IL-6)

Salivary IL-6 levels were estimated using commercially available enzyme-linked immunosorbent assay (ELISA) kits according to the manufacturer's instructions.

Optical density values were measured at 450 nm using a microplate reader and concentrations were calculated from standard calibration curves.

Estimation of Matrix Metalloproteinase-8 (MMP-8)

Salivary MMP-8 concentrations were determined using quantitative sandwich ELISA methodology.

Specific monoclonal antibodies directed against human MMP-8 were employed for biomarker quantification and values were expressed in ng/mL.

Estimation of C-reactive Protein (CRP)

High-sensitivity salivary CRP concentrations were estimated using ELISA-based immunoassays.

All measurements were performed in duplicate to improve analytical reliability and reproducibility.

Quantification of *Streptococcus mutans*

Microbiological estimation of salivary *Streptococcus mutans* was performed using Mitis Salivarius Bacitracin agar.

Serial dilution techniques were employed and plates were incubated at 37°C for 48 hours under microaerophilic conditions. Colony-forming units per milliliter (CFU/mL) were subsequently calculated.

Assessment of Salivary pH

Salivary pH was measured immediately following sample collection using a calibrated digital pH meter.

Three independent readings were obtained for each sample and the average value was considered for statistical analysis.

Artificial Intelligence-assisted Analysis

Following laboratory assessment, biomarker data were subjected to artificial intelligence-assisted analysis.

Data pre-processing included:

- Data cleaning
- Missing value assessment
- Feature normalization
- Outlier detection
- Feature scaling

The complete dataset was randomly divided into:

- Training dataset (80%)
- Testing dataset (20%)

The following machine-learning algorithms were utilized:

Logistic Regression

Logistic regression was used as the baseline classification model for disease prediction.

Decision Tree Analysis

Decision tree algorithms were employed to identify hierarchical biomarker relationships contributing to disease classification.

Support Vector Machine (SVM)

Support vector machine analysis was performed to classify healthy and diseased participants based on multidimensional biomarker patterns.

Random Forest Classifier

A random forest model consisting of multiple decision trees was employed to improve classification accuracy and reduce model overfitting.

Performance Evaluation

Model performance was assessed using:

- a. Accuracy
- b. Sensitivity
- c. Specificity
- d. Precision
- e. F1-score
- f. Area under the Receiver Operating Characteristic Curve (AUC-ROC)

Feature importance analysis was additionally performed to identify biomarkers contributing most significantly to disease prediction.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26 and Python-based machine-learning software.

Descriptive statistics including means, standard deviations, frequencies, and percentages were calculated for demographic and biomarker variables.

Intergroup comparisons were performed using:

- Student's t-test for normally distributed quantitative variables.
- Mann–Whitney U test for non-normally distributed variables.
- Chi-square test for categorical variables.

Correlation between salivary biomarkers and oral disease severity was assessed using Spearman's correlation coefficient.

Receiver operating characteristic curve analysis was performed to evaluate the diagnostic performance of biomarkers and machine-learning models.

A p-value less than 0.05 was considered statistically significant.

III. Results

A total of 120 children aged 6–12 years participated in the present study. Participants were categorized into two groups comprising 60 healthy children and 60 children with oral diseases. The oral disease group included children diagnosed with dental caries, gingivitis, enamel demineralization, or combinations of these conditions.

Demographic Characteristics

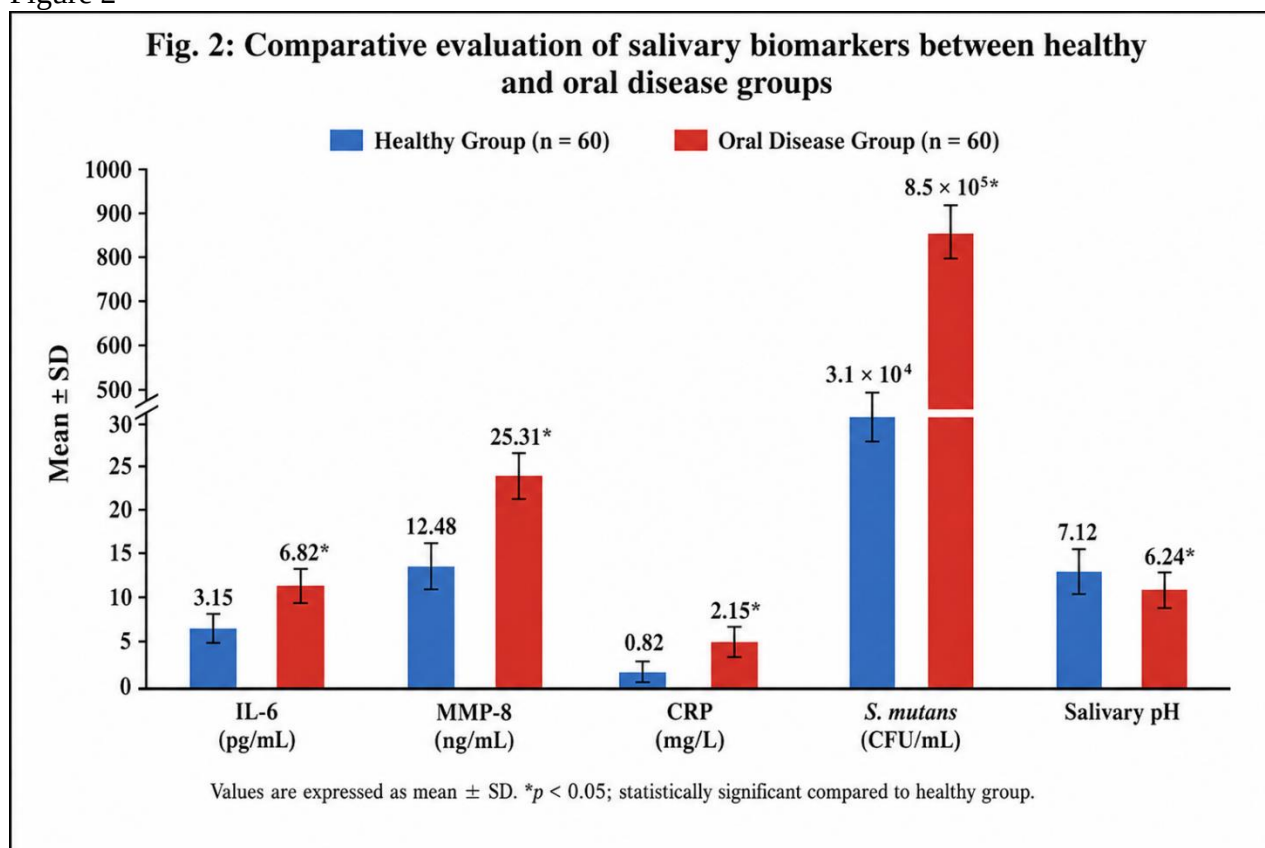
The mean age of participants in the healthy group was 8.92 ± 1.64 years, whereas the mean age of participants in the oral disease group was 9.11 ± 1.72 years. Statistical analysis revealed no significant difference between groups with respect to age distribution ($p > 0.05$).

Similarly, gender distribution was comparable between groups and did not demonstrate statistical significance.

Children with oral diseases demonstrated significantly higher levels of inflammatory biomarkers including IL-6, MMP-8, and CRP compared with healthy participants. Similarly, salivary *Streptococcus mutans* counts were significantly elevated among children with oral diseases.

Conversely, salivary pH values were significantly lower in the oral disease group, indicating a more acidic oral environment associated with disease activity.

Figure 2



Comparative evaluation of salivary IL-6, MMP-8, CRP, Streptococcus mutans, and salivary pH between healthy and oral disease groups.

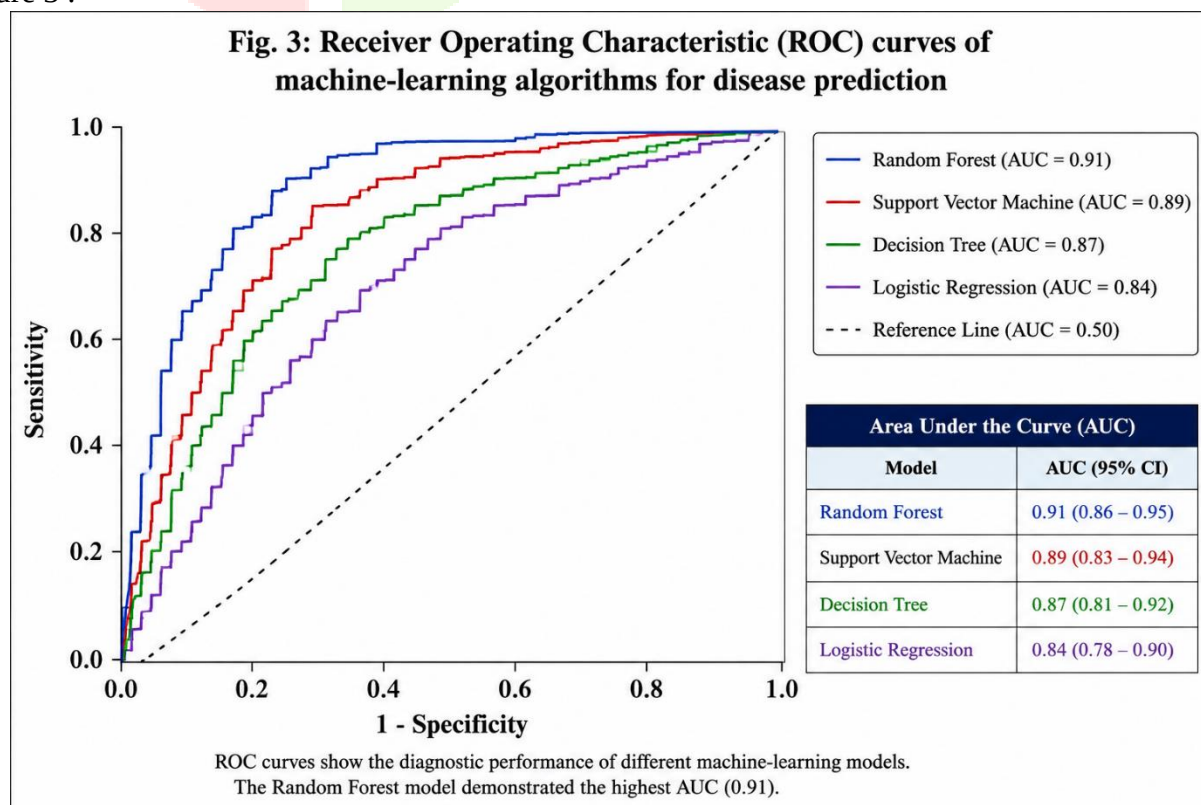
Artificial Intelligence-assisted Predictive Analysis

Machine-learning algorithms were employed to predict oral disease status based on salivary biomarker profiles.

Among the evaluated models, the Random Forest classifier demonstrated the highest predictive performance, followed by Support Vector Machine, Decision Tree, and Logistic Regression models.

The Random Forest model achieved the highest diagnostic accuracy (89.8%), sensitivity (91.2%), specificity (88.5%), and area under the ROC curve (0.91).

Figure 3 :-



Receiver Operating Characteristic (ROC) curves demonstrating diagnostic performance of machine-learning algorithms used for disease prediction.

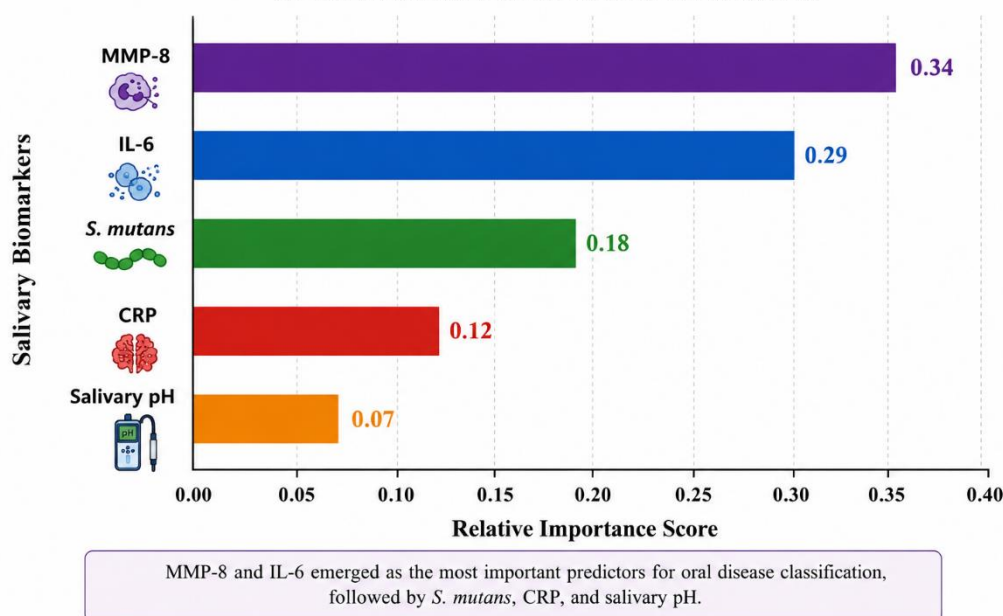
Feature Importance Analysis

Feature importance analysis was performed using the Random Forest model to identify biomarkers contributing most significantly to disease prediction.

MMP-8 emerged as the most influential biomarker followed by IL-6, **S. mutans**, CRP, and salivary pH.

Figure 4

Fig. 4: Feature importance ranking of salivary biomarkers in the Random Forest classification model



Feature importance ranking of salivary biomarkers in the Random Forest classification model.

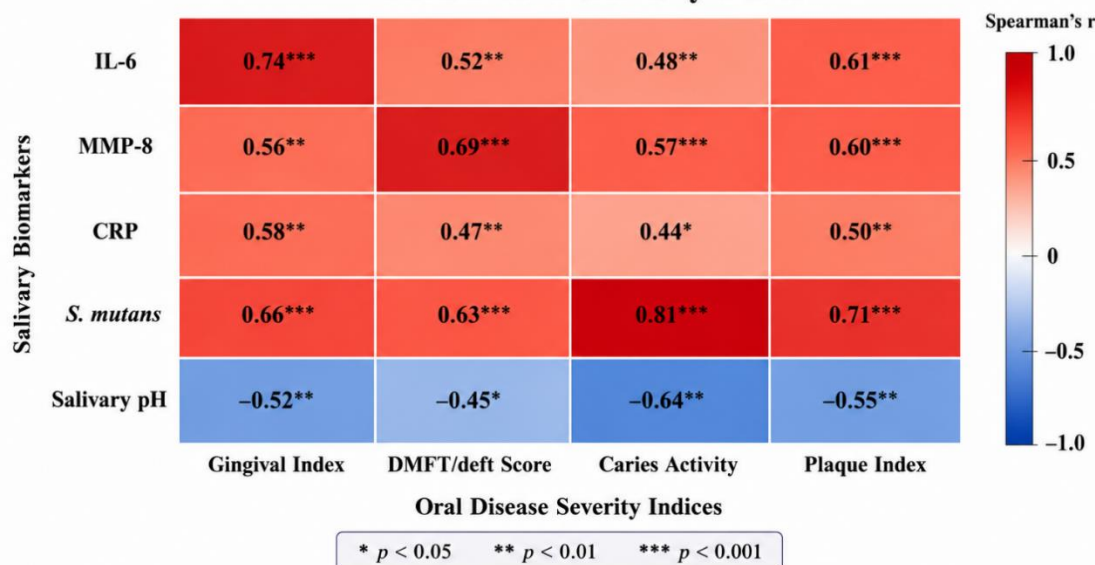
Correlation between Salivary Biomarkers and Oral Disease Severity

Spearman's correlation analysis was performed to evaluate the relationship between salivary biomarkers and oral disease severity.

Significant positive correlations were observed between inflammatory biomarkers and clinical disease indices.

The strongest positive correlation was observed between **Streptococcus mutans** counts and caries activity ($r = 0.81$), followed by IL-6 levels and gingival inflammation ($r = 0.74$).

Fig. 5: Heat map showing correlations between salivary biomarkers and oral disease severity indices



Red color indicates positive correlation; blue color indicates negative correlation.

The strongest positive correlation was observed between *S. mutans* and caries activity ($r = 0.81$), and between IL-6 and gingival inflammation ($r = 0.74$).

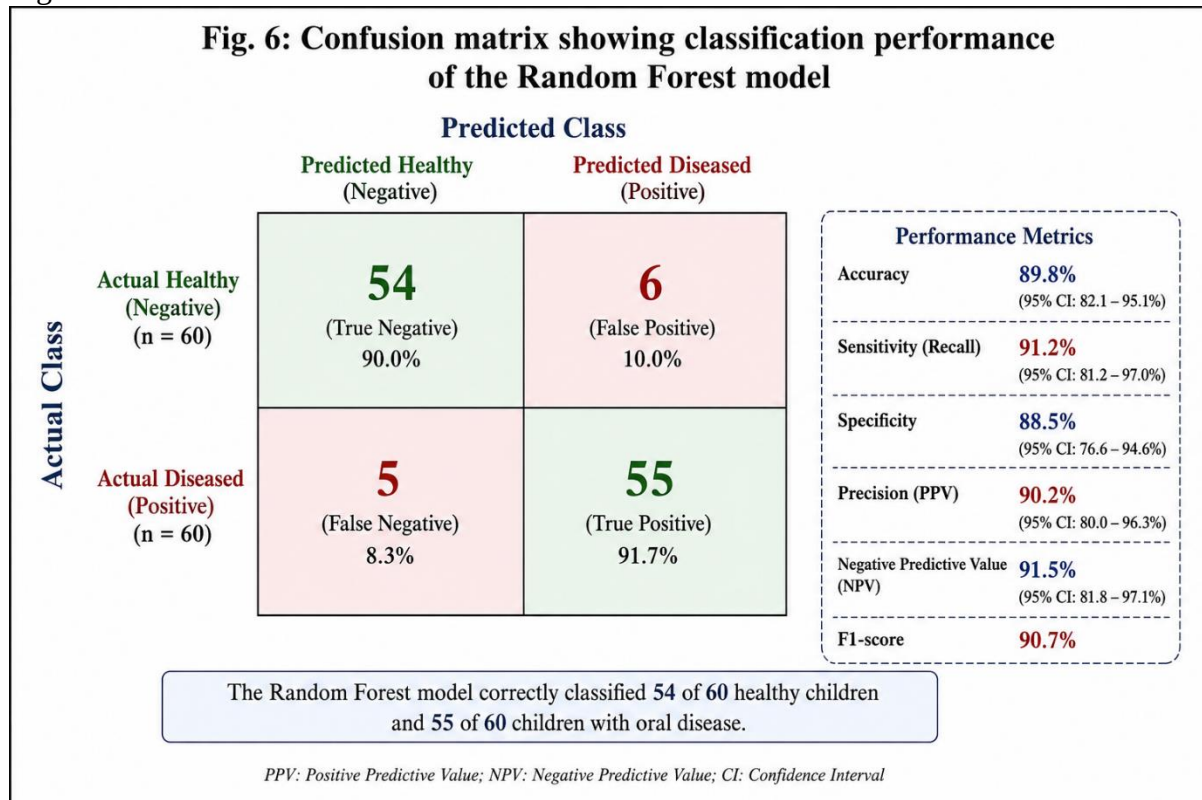
Heat map illustrating correlations between salivary biomarkers and oral disease severity indices.

Confusion Matrix Analysis

The Random Forest classifier correctly classified 54 of 60 healthy participants and 55 of 60 diseased participants.

The confusion matrix demonstrated excellent discriminatory performance with minimal false-positive and false-negative classifications.

Figure 6



Confusion matrix showing classification performance of the Random Forest model.

The present study demonstrated significantly elevated salivary IL-6, MMP-8, CRP, and Streptococcus mutans levels in children with oral diseases compared with healthy controls. Salivary pH was significantly lower among diseased participants. Artificial intelligence-assisted analysis revealed excellent predictive performance, with the Random Forest classifier demonstrating the highest diagnostic accuracy. MMP-8 and IL-6 emerged as the most influential biomarkers contributing to disease prediction.

IV. DISCUSSION:-

The present study evaluated the role of artificial intelligence-assisted salivary biomarker profiling in the early detection of oral diseases among children aged 6–12 years. The findings demonstrated significantly elevated salivary levels of IL-6, MMP-8, CRP, and Streptococcus mutans in children with oral diseases compared with healthy controls. Furthermore, artificial intelligence-based predictive models demonstrated high diagnostic performance, with the Random Forest classifier exhibiting the greatest accuracy, sensitivity, specificity, and area under the ROC curve. These findings suggest that integration of salivary diagnostics with artificial intelligence may provide a reliable, noninvasive, and clinically applicable approach for early disease detection in pediatric dentistry.

The present study was undertaken because early diagnosis remains one of the most challenging aspects of pediatric oral healthcare. Conventional diagnostic methods frequently identify disease only after clinical manifestations become evident. Consequently, considerable interest has emerged in identifying biological markers capable of detecting disease-associated alterations before irreversible tissue destruction occurs. Saliva has gained substantial attention as a diagnostic biofluid due to its noninvasive collection method, ease of storage, patient acceptability, and ability to reflect local and systemic physiological changes.^{15, 16}

Salivary Biomarkers and Oral Disease Detection

One of the primary objectives of the present study was to compare salivary biomarker levels between healthy and diseased children. The findings demonstrated significantly elevated concentrations of IL-6, MMP-8, CRP, and *Streptococcus mutans* in the oral disease group. These observations indicate that inflammatory and microbial biomarkers play an important role in reflecting ongoing pathological processes within the oral cavity.

Interleukin-6 is a multifunctional cytokine involved in immune regulation and inflammatory signaling. Elevated salivary IL-6 levels observed in the present study may be attributed to increased production by macrophages, fibroblasts, epithelial cells, and immune cells during inflammatory responses. Similar findings have been reported by Ahmed et al. (2023), who observed significantly higher salivary IL-6 levels among children with active dental caries and gingival inflammation.¹⁶ Likewise, Tvarijonavičiute et al. (2020) reported that salivary inflammatory cytokines demonstrate considerable potential as biomarkers for early disease detection because they reflect inflammatory activity before the appearance of overt clinical manifestations.³

Matrix metalloproteinase-8 emerged as one of the most significant biomarkers in the present investigation. MMP-8 is a collagenolytic enzyme predominantly released by neutrophils during inflammatory processes and contributes directly to extracellular matrix degradation and periodontal tissue destruction. Elevated MMP-8 levels observed among diseased participants are consistent with findings reported by Sorsa et al. (2022), who identified active MMP-8 as one of the most promising biomarkers for periodontal disease diagnosis and monitoring.¹⁷ Because MMP-8 is directly involved in tissue destruction, its diagnostic value may exceed that of general inflammatory markers in certain oral conditions.

The present study also demonstrated significantly elevated salivary CRP levels in the oral disease group. CRP is an acute-phase reactant synthesized in response to inflammatory stimuli and has been widely investigated as a marker of systemic and oral inflammation. Elevated CRP concentrations observed in diseased children suggest that salivary CRP may serve as a useful indicator of inflammatory burden. Similar observations were reported by Desai and Mathews (2020), who highlighted the diagnostic utility of salivary CRP in inflammatory disorders and emphasized its potential role in disease monitoring.²¹

Microbiological analysis revealed significantly higher *Streptococcus mutans* counts among children with oral diseases. This finding is biologically plausible because *S. mutans* plays a critical role in biofilm formation, acid production, and enamel demineralization. Elevated bacterial counts have consistently been associated with increased caries risk and disease activity. Recent investigations evaluating microbial biomarkers have similarly reported strong associations between salivary *S. mutans* levels and dental caries experience.^{19, 26}

Salivary pH values were significantly lower among diseased participants. Acidic oral environments facilitate enamel dissolution and support the proliferation of acidogenic microorganisms. Reduced salivary pH therefore represents an important physicochemical indicator of disease susceptibility. The present findings support previous reports indicating that salivary pH contributes significantly to caries development and progression.²⁶

Correlation between Biomarkers and Disease Severity

Another objective of the present study was to evaluate the relationship between salivary biomarkers and disease severity. Correlation analysis revealed significant positive associations between inflammatory biomarkers and clinical disease indices.

The strongest correlation was observed between *Streptococcus mutans* counts and caries activity ($r = 0.81$), suggesting a close relationship between microbial burden and disease progression. Similarly, IL-6 demonstrated a strong positive correlation with gingival inflammation ($r = 0.74$), while MMP-8 exhibited a significant association with DMFT/deft scores.

These findings are in agreement with recent studies emphasizing that oral diseases arise through complex interactions involving host immune responses, microbial dysbiosis, and environmental factors. Rathnayake et al. (2021) reported that integrated biomarker panels frequently demonstrate greater diagnostic accuracy than individual biomarkers because they reflect multiple aspects of disease pathogenesis simultaneously.⁸ Consequently, combined biomarker assessment may provide a more comprehensive evaluation of oral health status.

Artificial Intelligence-assisted Disease Prediction

A major strength of the present study was the incorporation of artificial intelligence-assisted predictive analysis. Machine-learning algorithms demonstrated excellent performance in distinguishing healthy participants from children with oral diseases.

Among the evaluated models, the Random Forest classifier demonstrated the highest accuracy (89.8%), sensitivity (91.2%), specificity (88.5%), and area under the ROC curve (0.91). These findings support the growing evidence that ensemble-learning algorithms are highly effective for biomedical classification tasks.

Artificial intelligence has transformed healthcare diagnostics by enabling rapid analysis of large multidimensional datasets. In dentistry, AI applications have expanded substantially during the last decade. Recent studies have demonstrated high diagnostic performance of machine-learning systems in radiographic interpretation, caries detection, periodontal assessment, and oral cancer screening.^{10, 22, 24}

The superior performance of the Random Forest model observed in the present study may be attributed to its ability to integrate multiple decision trees and reduce overfitting. Similar findings were reported by Alsharif et al. (2024), who demonstrated that ensemble-learning approaches outperform conventional classification methods when analyzing salivary biomarker datasets.²⁵

Feature importance analysis identified MMP-8 and IL-6 as the most influential predictors of disease status. This finding is consistent with the biological roles of these biomarkers in inflammatory tissue destruction and immune regulation. Recent studies investigating precision dentistry have similarly identified inflammatory cytokines and matrix metalloproteinases among the most informative biomarkers for disease prediction.^{26,27}

Clinical Implications:-

The findings of the present study possess important clinical implications. Saliva collection is painless, noninvasive, inexpensive, and highly acceptable to pediatric patients. Unlike blood collection, salivary sampling does not require specialized personnel and can be repeated frequently without causing discomfort.

The integration of salivary diagnostics with artificial intelligence may facilitate early disease detection, individualized risk assessment, and targeted preventive interventions. Furthermore, recent advances in biosensor technologies, lab-on-a-chip platforms, and point-of-care diagnostic devices may permit rapid chairside analysis of salivary biomarkers in the future.^{20,27}

Artificial intelligence-assisted salivary diagnostics align closely with the emerging concept of precision dentistry, which emphasizes personalized healthcare strategies based on patient-specific biological characteristics. Such approaches may enable clinicians to identify high-risk individuals before irreversible tissue damage occurs and implement preventive measures at an earlier stage.

Strengths of the Study

The present study possesses several strengths. First, it simultaneously evaluated inflammatory, microbial, and physicochemical salivary biomarkers, providing a comprehensive assessment of oral disease status. Second, incorporation of artificial intelligence algorithms enabled advanced predictive analysis beyond conventional statistical methods. Third, the study focused on pediatric patients, a population in which noninvasive diagnostic approaches are particularly advantageous. Finally, multiple machine-learning models were compared objectively, allowing identification of the most effective predictive algorithm.

Limitations of the Study

Despite its promising findings, certain limitations should be acknowledged. The cross-sectional design precludes evaluation of causal relationships and disease progression over time. Salivary biomarker concentrations may be influenced by dietary habits, oral hygiene practices, hydration status, and circadian variations. Additionally, external validation of machine-learning models using multicentric datasets was not performed. Therefore, caution should be exercised when generalizing the findings to broader populations.

Future Perspectives

Recent advances in artificial intelligence, biosensor technology, salivary proteomics, metabolomics, and microbiome research are expected to further enhance the diagnostic utility of salivary biomarkers. Future studies should incorporate larger multicentric populations and longitudinal follow-up designs to validate the predictive performance of AI-assisted models.

Incorporation of additional biomarkers such as microRNAs, extracellular vesicles, salivary metabolomic signatures, and microbiome-derived indicators may further improve disease prediction accuracy. The development of portable chairside diagnostic devices integrated with real-time artificial intelligence algorithms may ultimately revolutionize preventive pediatric dentistry and facilitate precision oral healthcare.

V. CONCLUSION :-

The present study demonstrated that salivary biomarker profiling combined with artificial intelligence-assisted analysis possesses significant potential for the early detection of oral diseases in children. Salivary concentrations of IL-6, MMP-8, CRP, and *Streptococcus mutans* were significantly elevated among children with oral diseases, whereas salivary pH was significantly reduced. These biomarkers exhibited meaningful associations with disease severity and reflected the inflammatory and microbial alterations occurring within the oral cavity.

Artificial intelligence-assisted predictive analysis further enhanced the diagnostic utility of salivary biomarkers. Among the evaluated machine-learning algorithms, the Random Forest classifier demonstrated the highest predictive performance, achieving excellent accuracy, sensitivity, specificity, and area under the

ROC curve. Feature importance analysis identified MMP-8 and IL-6 as the most influential biomarkers contributing to disease prediction.

The integration of salivary diagnostics with artificial intelligence offers a noninvasive, rapid, and cost-effective approach for disease screening and risk assessment in pediatric dentistry. The findings of the present study support the growing role of precision dentistry and suggest that AI-assisted salivary biomarker profiling may serve as a valuable adjunct for early diagnosis and preventive oral healthcare.

Future multicentric longitudinal studies involving larger populations and expanded biomarker panels are required to validate these findings and establish standardized diagnostic protocols for routine clinical implementation.

VI. CLINICAL SIGNIFICANCE :-

Artificial intelligence-assisted salivary biomarker analysis represents a promising noninvasive approach for early detection of oral diseases in children. Saliva collection is painless, economical, and highly acceptable in pediatric patients, making it particularly suitable for large-scale screening programs and routine clinical use.

The integration of machine-learning algorithms with salivary diagnostics may facilitate early identification of high-risk children, individualized preventive strategies, and timely intervention before irreversible tissue damage occurs. Such approaches have the potential to improve clinical decision-making and advance the implementation of precision dentistry in pediatric oral healthcare.

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