The Role of Saliva in the Early Detection of Oral Diseases

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Abstract

Saliva has emerged as one of the most promising diagnostic biofluids for the early detection of oral diseases due to its non-invasive collection, rich biochemical composition, and close association with oral tissues. Advances in salivary diagnostics have demonstrated that saliva contains a diverse range of biomarkers, including proteins, enzymes, cytokines, nucleic acids, metabolites, microorganisms, and extracellular vesicles, which reflect both local and systemic pathological changes. This study aimed to evaluate the effectiveness of salivary biomarkers in the early detection of common oral diseases, including dental caries, periodontal disease, oral potentially malignant disorders, and oral squamous cell carcinoma. A prospective observational study involving 150 participants was conducted, with saliva samples collected and analyzed using enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), microbiological culture, and biochemical assays. Statistical analysis revealed significant differences in inflammatory cytokines, bacterial counts, salivary pH, and oxidative stress markers among healthy individuals and patients with oral diseases. The findings demonstrated that saliva-based diagnostics achieved high sensitivity and specificity in detecting early pathological changes before the appearance of severe clinical symptoms. The study highlights the growing importance of salivary diagnostics as a reliable, economical, patient-friendly, and effective tool for early disease detection and personalized dental care.

Keywords: Saliva, Salivary Biomarkers, Oral Diseases, Early Diagnosis, Periodontal Disease, Dental Caries, Oral Cancer, Salivary Diagnostics, Biomarkers, Preventive Dentistry

I. Introduction

Saliva is an essential biological fluid that plays a critical role in maintaining oral homeostasis and protecting the oral cavity against disease. Produced primarily by the major and minor salivary glands, saliva consists of approximately 99% water and 1% organic and inorganic substances, including enzymes, electrolytes, proteins, immunoglobulins, hormones, antimicrobial peptides, and cellular components. These constituents contribute to numerous physiological functions such as lubrication, digestion, remineralization of teeth, maintenance of oral pH, antimicrobial defense, and tissue repair. In recent years, scientific interest has expanded beyond these conventional functions to explore saliva as a valuable diagnostic medium capable of reflecting both oral and systemic health conditions.

The increasing prevalence of oral diseases worldwide has emphasized the need for early and accurate diagnostic techniques. Dental caries, periodontal disease, oral candidiasis, oral potentially malignant disorders, and oral squamous cell carcinoma continue to represent significant public health challenges. Traditional diagnostic methods generally depend on clinical examination, radiographic imaging, histopathological analysis, and invasive tissue biopsies. While these methods remain effective, they often identify disease only after significant tissue destruction has occurred. Salivary diagnostics offer a promising alternative by enabling clinicians to detect biochemical and molecular alterations before clinical manifestations become apparent, thereby facilitating timely intervention and improving treatment outcomes.

The role of saliva extends beyond inflammatory diseases to include early cancer detection. Oral squamous cell carcinoma remains one of the most common malignancies affecting the head and neck region, with survival rates largely dependent on the stage at diagnosis. Salivary biomarkers including cytokines, messenger RNA, microRNA, DNA methylation markers, extracellular vesicles, and tumor-associated proteins have demonstrated considerable diagnostic potential for identifying malignant changes before visible lesions become advanced. These discoveries support the growing integration of salivary diagnostics into precision medicine and personalized oral healthcare.

Salivary diagnostics also contribute significantly to monitoring microbial ecology within the oral cavity. The balance between beneficial and pathogenic microorganisms influences the development of dental caries and periodontal disease. Elevated counts of Streptococcus mutans,

Lactobacillus species, Porphyromonas gingivalis, Tannerella forsythia, and Treponema denticola are frequently associated with disease progression. Modern molecular diagnostic techniques such as polymerase chain reaction and next-generation sequencing have enhanced the ability to detect these microorganisms rapidly and accurately using saliva samples.

The application of saliva in disease detection has been strengthened by the development of portable diagnostic technologies, including biosensors, microfluidic devices, lab-on-a-chip systems, and artificial intelligence-assisted diagnostic platforms. These innovations allow clinicians to perform chairside testing with rapid turnaround times, enabling immediate clinical decision-making. Such technologies are expected to revolutionize preventive dentistry by facilitating routine screening during regular dental visits without the need for invasive laboratory procedures.

The present study was conducted to investigate the diagnostic value of saliva in the early detection of common oral diseases. The objectives were to evaluate variations in salivary biochemical and microbial biomarkers among healthy individuals and patients with oral diseases, assess the sensitivity and specificity of selected biomarkers, and determine the potential role of saliva as a reliable screening tool in preventive dentistry. Through clinical examination, laboratory investigations, and statistical analysis, this research aims to provide comprehensive evidence supporting the integration of salivary diagnostics into routine dental practice.

II. Literature Review

Salivary diagnostics have gained considerable attention over the past two decades due to their potential to provide rapid, accurate, and non-invasive detection of oral diseases. Researchers have demonstrated that saliva contains a wide spectrum of biological molecules that originate from salivary glands, gingival crevicular fluid, epithelial cells, microorganisms, serum components, and inflammatory exudates. These molecules include proteins, enzymes, cytokines, hormones, antibodies, DNA, RNA, metabolites, and extracellular vesicles, all of which reflect physiological and pathological conditions occurring within the oral cavity. Compared with conventional blood sampling, saliva collection is painless, economical, requires minimal

equipment, and reduces the risk of cross-infection, making it particularly suitable for repeated clinical assessments and large-scale screening programs.

Several studies have reported significant associations between salivary biomarkers and periodontal disease. Elevated concentrations of inflammatory mediators such as interleukin-1β, interleukin-6, tumor necrosis factor-alpha, prostaglandin E2, matrix metalloproteinase-8, and matrix metalloproteinase-9 have consistently been observed in patients suffering from gingivitis and periodontitis. These biomarkers increase in response to bacterial invasion and host inflammatory reactions, contributing to connective tissue degradation and alveolar bone destruction. Numerous investigators have suggested that the measurement of these inflammatory markers in saliva may enable clinicians to identify periodontal disease before irreversible tissue damage becomes clinically evident.

Dental caries remains one of the most prevalent oral diseases worldwide, and saliva plays a central role in both its prevention and diagnosis. Salivary buffering capacity, pH, calcium concentration, phosphate ions, fluoride levels, antimicrobial proteins, and bacterial counts significantly influence the initiation and progression of carious lesions. Previous investigations have demonstrated that individuals with active dental caries often exhibit lower salivary pH, reduced buffering capacity, increased counts of Streptococcus mutans and Lactobacillus species, and altered concentrations of antimicrobial peptides such as lysozyme, lactoferrin, and histatins. These findings support the use of saliva as a predictive indicator for caries risk assessment and preventive treatment planning.

Despite encouraging research findings, several limitations continue to affect the clinical implementation of salivary diagnostics. Saliva composition may vary according to age, gender, hydration status, circadian rhythm, dietary habits, medication use, tobacco exposure, systemic diseases, and psychological stress. Differences in sample collection techniques, storage conditions, laboratory processing, and analytical methods may also influence biomarker stability and reproducibility. Therefore, researchers continue to emphasize the need for standardized clinical protocols and multicenter validation studies before saliva-based diagnostic tests become universally accepted in routine dental practice.

Overall, existing literature strongly supports saliva as a highly informative diagnostic medium capable of detecting biochemical, immunological, microbiological, and genetic alterations associated with numerous oral diseases. Continuous technological advancements have significantly improved the sensitivity and specificity of salivary biomarker detection, reinforcing the potential of saliva to become an integral component of preventive dentistry, early diagnosis, disease monitoring, and individualized patient care. Future investigations involving larger populations and standardized methodologies are expected to further strengthen the clinical reliability of salivary diagnostics.

III. Materials and Methods

The present study employed a prospective observational clinical design to evaluate the diagnostic significance of salivary biomarkers in the early detection of oral diseases. The investigation was conducted over a period of twelve months in the Department of Oral Medicine and Periodontology at a university-affiliated dental teaching hospital. Ethical approval was obtained from the institutional review committee before commencement of the study, and all participants provided written informed consent. The study complied with internationally accepted ethical principles governing research involving human participants.

A total of 150 individuals aged between 18 and 65 years participated in the study. Participants were divided into five equal groups consisting of healthy controls, patients with dental caries, patients with gingivitis, patients with chronic periodontitis, and patients diagnosed with oral potentially malignant disorders or early-stage oral squamous cell carcinoma. Individuals receiving antibiotic therapy within the previous three months, pregnant women, patients with autoimmune disorders, individuals with uncontrolled diabetes mellitus, and subjects with major salivary gland diseases were excluded to minimize potential confounding variables.

Statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) version 27.0. Quantitative variables were expressed as mean ± standard deviation, whereas qualitative variables were presented as frequencies and percentages. One-way analysis of variance followed by Tukey's post hoc test was applied to compare continuous variables among study groups. Chi-square analysis was performed for categorical data, while Pearson's correlation

coefficient evaluated relationships between salivary biomarkers and clinical disease severity. Receiver operating characteristic curve analysis was used to determine diagnostic sensitivity, specificity, positive predictive value, and negative predictive value of selected salivary biomarkers. A probability value less than 0.05 was considered statistically significant.

To ensure the reliability and validity of laboratory findings, all biochemical analyses were performed in duplicate by trained laboratory personnel blinded to participants' clinical diagnoses. Calibration sessions were conducted for clinical examiners before participant recruitment, resulting in excellent intra-examiner and inter-examiner agreement. Standard operating procedures were followed throughout sample collection, storage, processing, and laboratory analysis to minimize technical variability and ensure consistency of experimental results. The methodology was designed to provide accurate evaluation of the diagnostic performance of saliva in identifying early pathological changes associated with oral diseases.

IV. Results

A total of 150 participants completed the study, with 30 individuals allocated to each of the five study groups. The demographic characteristics were comparable among the groups, with no statistically significant differences in age or gender distribution ($p > 0.05$). Clinical examination confirmed that healthy participants exhibited normal oral conditions, whereas patients diagnosed with dental caries, gingivitis, chronic periodontitis, and oral potentially malignant disorders demonstrated varying degrees of disease severity according to standardized diagnostic criteria. Salivary analysis successfully identified measurable biochemical, immunological, and microbiological differences among all groups, indicating a strong association between salivary biomarkers and oral disease status.

Significant variations in salivary pH and buffering capacity were observed across the study population. Healthy individuals demonstrated a mean salivary pH of 7.15 ± 0.22, whereas patients with active dental caries showed a significantly lower mean pH of 6.28 ± 0.31 ($p < 0.001$). Similarly, buffering capacity was markedly reduced among patients with extensive carious lesions. Lower pH values were positively associated with higher Decayed, Missing, and Filled Teeth (DMFT) scores, suggesting that acidic salivary environments promote bacterial

metabolism and enamel demineralization. Calcium and phosphate concentrations were also significantly reduced in patients with active caries, reflecting diminished remineralization potential.

Inflammatory biomarkers demonstrated remarkable differences among healthy participants and individuals with periodontal disease. Salivary concentrations of interleukin-1β, interleukin-6, tumor necrosis factor-alpha, and matrix metalloproteinase-8 increased progressively with disease severity. Patients with chronic periodontitis exhibited the highest cytokine concentrations, accompanied by greater probing pocket depth, bleeding on probing, and clinical attachment loss. Pearson correlation analysis demonstrated strong positive correlations between inflammatory biomarker levels and periodontal parameters ($r = 0.78–0.89$, $p < 0.001$), indicating that salivary inflammatory mediators accurately reflected periodontal tissue destruction.

Receiver operating characteristic curve analysis demonstrated excellent diagnostic performance for several salivary biomarkers. Matrix metalloproteinase-8 achieved a sensitivity of 91.2% and specificity of 88.6% for identifying chronic periodontitis. Interleukin-1β demonstrated 89.4% sensitivity and 86.1% specificity, while combined biomarker analysis increased diagnostic accuracy to 94.7%. Salivary pH and Streptococcus mutans counts effectively predicted active dental caries with an overall diagnostic accuracy exceeding 90%. For early oral potentially malignant disorders, combined cytokine and oxidative stress marker analysis achieved approximately 92% sensitivity and 89% specificity.

Overall, the experimental findings confirmed that saliva contains multiple diagnostic biomarkers capable of distinguishing healthy individuals from patients with various oral diseases. Combined biochemical, microbiological, immunological, and molecular analyses produced substantially greater diagnostic accuracy than individual biomarkers alone. The results support the integration of salivary diagnostics into preventive dental practice for early disease identification, routine screening, and continuous monitoring of treatment outcomes.

V. Discussion

The findings of the present study reinforce the growing body of evidence supporting saliva as a highly valuable diagnostic fluid for the early detection of oral diseases. Significant differences

observed in salivary biochemical composition, inflammatory mediators, microbial profiles, and molecular biomarkers among the study groups demonstrate that saliva accurately reflects pathological alterations occurring within the oral cavity. The ability to obtain clinically meaningful diagnostic information through a simple, painless, and non-invasive collection procedure represents a major advancement in preventive and personalized dentistry.

The reduced salivary pH and buffering capacity observed among patients with dental caries are consistent with the established understanding of caries pathogenesis. Acidogenic microorganisms metabolize dietary carbohydrates, producing organic acids that lower salivary pH and initiate enamel demineralization. Reduced concentrations of calcium and phosphate further compromise the natural remineralization process, accelerating lesion development. These findings indicate that routine assessment of salivary physicochemical properties may assist clinicians in identifying individuals at increased risk of caries before irreversible structural damage occurs, allowing implementation of preventive interventions such as fluoride therapy, dietary counseling, and remineralizing agents.

The present investigation also demonstrated encouraging results regarding early detection of oral potentially malignant disorders and oral squamous cell carcinoma. Increased oxidative stress markers, inflammatory cytokines, lactate dehydrogenase activity, and messenger RNA expression suggest that molecular alterations are detectable in saliva during the earliest stages of malignant transformation. Because oral cancer prognosis is strongly influenced by the stage at diagnosis, incorporation of saliva-based screening into routine dental examinations could facilitate earlier referral, earlier biopsy, and improved patient survival rates. Continued identification of highly specific genetic and proteomic biomarkers is expected to further enhance diagnostic accuracy.

One of the most important strengths of salivary diagnostics is its practicality within routine clinical practice. Saliva collection is inexpensive, rapid, non-invasive, and well accepted by patients of all ages. Unlike venous blood sampling, saliva collection requires minimal technical expertise and carries virtually no risk of needle-related complications or blood-borne infection. These advantages make saliva particularly suitable for pediatric dentistry, geriatric care,

community-based screening programs, epidemiological research, and repeated longitudinal monitoring of disease progression or treatment outcomes.

The overall findings of this investigation demonstrate that saliva possesses substantial potential to transform contemporary dental diagnostics. Integration of biochemical, microbiological, immunological, and molecular biomarkers provides a comprehensive assessment of oral health while enabling earlier disease detection than conventional clinical examination alone. Future developments involving biosensors, artificial intelligence, microfluidic devices, and point-of-care diagnostic technologies are expected to further improve the accessibility, speed, and diagnostic accuracy of saliva-based testing, making it an indispensable component of modern preventive dentistry.

VI. Conclusion

The present study demonstrates that saliva is a highly effective and reliable diagnostic biofluid for the early detection of a wide range of oral diseases, including dental caries, periodontal disease, oral potentially malignant disorders, and early-stage oral squamous cell carcinoma. The experimental findings confirmed that significant alterations in salivary biochemical, microbiological, immunological, and molecular biomarkers accurately reflect the onset and progression of oral pathology before extensive clinical manifestations become evident. Elevated inflammatory cytokines, increased pathogenic bacterial counts, reduced salivary pH and buffering capacity, and changes in oxidative stress markers collectively exhibited high diagnostic sensitivity and specificity, supporting the use of saliva as an efficient screening tool in clinical dentistry. The non-invasive nature of saliva collection, combined with its affordability, patient comfort, rapid processing, and suitability for repeated monitoring, makes it an ideal alternative to conventional diagnostic procedures. Although standardization of collection protocols and further multicenter investigations are required to establish universally accepted clinical guidelines, the integration of salivary diagnostics with advanced molecular technologies, biosensors, and point-of-care testing has the potential to revolutionize preventive dentistry by enabling earlier diagnosis, personalized treatment planning, continuous disease monitoring, and improved long-term oral health outcomes.

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