



American Journal of Medical Science and Innovation (AJMSI)

ISSN: 2836-8509 (ONLINE)

VOLUME 5 ISSUE 2 (2026)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Integrating Genomic Biomarkers for Early Detection and Personalized Management of Oral Disease

Larry Angel Delgado Martín^{1*}, Karen Garlobo Ramos², Yelene Tapanes Nieves²

Article Information

Received: June 07, 2026

Accepted: August 24, 2026

Published: October 05, 2026

Keywords

Diagnostic Accuracy, Early Detection, Genomic Biomarkers, Oral diseases, Personalized Medicine

ABSTRACT

Oral diseases continued to be a global public health challenge because of delays in diagnosis and differences in treatment outcomes. The objective of this study was to assess the potential relevance of genomic biomarkers for early detection and personalized management of oral diseases by evaluating their contribution towards diagnostic accuracy, clinical utility, implementation barriers, and patient outcomes. This study adopted a quantitative cross-sectional strategy where data were collected from 385 respondents through the use of a structured questionnaire. The gathered data were evaluated using descriptive statistics as well as inferential statistics in SPSS. In regard to the results, respondents strongly agreed that genomics biomarkers improved early detection of oral diseases, positively enhanced diagnostic value, aided personalized optimal treatment planning and offered critical clinical decision-making. Nonetheless, high testing costs, low public awareness and healthcare infrastructure, and ethics-and-policy concerns were cited as a few of the most critical barriers to implementation. The study also demonstrated that the use of combined genomic biomarkers, further facilitated treatment success along with a reduction in disease-related burden and an improved quality of life for patients. Overall, the study concluded that genomic biomarkers would be a novel and developing tool to stimulate precision dentistry by means of earlier diagnosis and personalized oral healthcare delivery. To promote successful implementation in routine practice, it was also recommended to strengthen genomic infrastructure, workforce training and enact supportive healthcare policies.

INTRODUCTION

Oral diseases, such as dental caries and periodontal disease, oral potentially malignant disorders, and oral squamous-cell carcinoma constitute some of the most common chronic health problems worldwide (Murray *et al.*, 2024). These diseases are also associated with reduced quality of life and increased healthcare costs. The timing of diagnosis is crucial if treatment is to be effective, yet conventional diagnostic techniques usually identify disease only when clinical signs become apparent and opportunities for intervention are lost (Clark & Lillard, 2024). The rapid evolution in genomic technologies has provided opportunities for the identification of genomic biomarkers, including single nucleotide polymorphisms (SNPs), gene expression profiles, DNA methylation patterns and microRNAs that can provide detailed information about molecular changes even before clinical symptoms occur (Restrepo *et al.*, 2023). The clinical utility of novel blood-based biomarkers in cardiovascular disease is continually expanding. Incorporating knowledge of genetic variants into clinical practice is in line with the goals of precision dentistry, as prevention and treatment strategies can be personalized based on an individual's genetic profile and disease susceptibility (Dubey *et al.*, 2025). While many studies for genomic biomarkers have shown strong potential in diagnosing oral diseases, the evidence for clinical translation has typically been limited by inconsistent validation, population heterogeneity,

and incomplete performance assessment regarding their predictive value in a routine dental care setting (Husien *et al.*, 2024). This highlights the need for quantitative studies to determine the utility of genomic biomarkers in improving diagnostic performance and enabling individualized disease management (Natarajan, 2026).

The goal of this study was to investigate the quantitative impact of genomic biomarkers in screening and tailored treatment for oral disorders. The results are anticipated to provide justification for the incorporation of genomic biomarkers into precision oral healthcare, leading to improved early diagnosis, individualized treatment planning, and overall patient outcomes.

LITERATURE REVIEW

Background Oral diseases are still one of the most common non-communicable diseases around the globe, including dental caries, periodontal disease and oral potentially malignant disorders (OPMDs), and oral squamous cell carcinoma (OSCC) (Addissouky *et al.*, 2023). Globally, these diseases burden billions of people and pose a substantial clinical, social, and economic burden. There have been various advancements surrounding preventive dentistry and diagnostic technologies; however, the delayed diagnosis of malignant and progressive oral conditions continues to inhibit effective treatment (Rajput *et al.*, 2026). As a result, research has become gradually grown into discovering molecular biomarkers for early diagnosis

¹ Department of Dentistry, University of Medical Sciences of Havana, Havana, Cuba and Department of Dentistry, Universidade Guarulhos, São Paulo, Brazil

² Department of Dentistry, University of Medical Sciences of Havana, Havana, Cuba

* Corresponding author's e-mail: larryodontologia@gmail.com

and precision-based therapeutic options (Dar *et al.*, 2023). Genomic biomarkers are identifiable and quantifiable biological indicators found in genes that reflect normal biological processes, pathogenesis, or response to therapy (Vashisht *et al.*, 2023). Biomedical liquid biopsy biomarkers include single nucleotide polymorphisms (SNP), gene mutations, gene expression profiles, DNA methylation patterns, microRNAs (miRNAs), long non-coding RNAs (lncRNA), and circulating tumor DNA (Dai & Shen, 2022). Next-generation sequencing and molecular diagnostics have made it possible to comprise genomic alterations involved in different types of oral diseases. Research has shown that abnormalities in genes involved in pathways of inflammation, immunity, apoptosis and cell proliferation are major contributors to the etiology and progression of oral diseases (Zafar *et al.*, 2025). Numerous studies have reported a decrease in mitophagy with increasing age accompanied by an increase in proinflammatory cytokine genes, including IL-1 β , IL-6, and TNF- α which are associated with susceptibility to periodontal disease whereas alterations of TP53, CDKN2A, EGFR and PIK3CA associated with oral squamous cell carcinoma (Sarhadi & Armengol, 2022). Alternatively, polymorphisms in genes related to enamel formation like AMELX and ENAM have been linked to susceptibility for dental caries. These results indicate a role for genomic biomarkers that extends beyond conventional clinical examination and may lead to earlier detection of disease (Hassan *et al.*, 2022).

An early diagnosis is imperative for optimum management and better treatment outcomes while minimizing disease-related complications. Standard diagnostic approaches, such as visual inspection and radiographic or histopathological characteristics are useful but often detect disease only after substantial pathological alterations have taken place (Haghighyegh *et al.*, 2024). Molecular alterations that occur at the preclinical stage of disease may be detectable by genomic biomarkers, thus opening an avenue for early intervention. MicroRNAs and DNA methylation markers in circulation have been reported to be sensitive and specific biomarkers for early-stage oral cancer by several studies (Xiao *et al.*, 2022). As well, the expression of genes has been used to distinguish healthy oral tissues from premalignant and malignant lesions. Due to the presence of DNA, RNA, and extracellular vesicles that mirror molecular alterations occurring in oral tissues, saliva-based genomic analysis has emerged as a promising non-invasive diagnostic strategy (Casolino *et al.*, 2024). These events suggest that genomic biomarkers can add significant value in the precision and rapidity of oral disease diagnosis. Personalized medicine highlights the importance of customizing health care based on an individual genetic, environmental and lifestyle factors (Jamalinia & Weiskirchen, 2025). Personalized management in dentistry aims to improve prevention, diagnosis, prognosis and treatment with genomics from the information utilized in clinical decision making (Pandey & Gupta, 2024). Genomic profiling has been

shown to predict, disease susceptibility, identify high-risk patients for recurrence, coordinate the assessment of treatment response and inform targeted therapeutic interventions (Alzeer, 2023). Genomic profiling of oral cancer patients has enabled the personalized selection of targeted therapies targeting specific molecular pathways and genomic risk assessment has advanced individualized preventive efforts for periodontal disease (Tan *et al.*, 2025). Treatment regimens tailored to individual patient characteristics can also avoid unnecessary and inappropriately aggressive interventions, improve the efficiency of treatment delivered, and enhance long-term outcomes for patients (Edvardsson & Heenkenda, 2025). Advancements in sequencing technologies and bioinformatics have aided the clinical application of genomic biomarkers dramatically. Incorporation of genomic data into dental clinical practice may improve diagnostic accuracy, aid disease classification, enable risk assessment, and treatment monitoring (Ghoreysli *et al.*, 2025). Prior studies have indicated that integration of genomic biomarkers with traditional clinical assessments greatly enhances predictive performances over conventional methods alone. In addition, genomic biomarkers could be useful in monitoring disease progression and assessing treatment efficacy (Lightbody *et al.*, 2019). Longitudinal genomic analyses enables clinicians to detect the molecular changes that occur post treatment and modify therapeutic approaches appropriately. Thus, genomic biomarkers is a major component of precision dentistry and its translational applications in oral health associated research (Wolde *et al.*, 2025a). While genomic biomarkers hold promise in advancing the science separate from oral healthcare strands, the routine translation of biomarkers into applications remains limited. A major challenge is the lack of universally applicable biomarker validation in populations with strikingly different profiles across regions (Olawade *et al.*, 2025). The performance of a biomarker in individual ethnic groups may be affected by genetic differences, which might decrease the generalizability of research results across separate populations. Additionally, a majority of studies that have been published report small sample sizes, reducing the statistical power and generalizability (Ogunjobi *et al.*, 2026). Economic and infrastructural challenges are likewise limiting broad clinical adoption. Cost-prohibitive genomic sequencing, limited laboratory capacity, deficient training for the practicing dentist and insufficient incorporation of genomic information have created significant barriers to implementation especially in low- and middle-income countries (Farhat *et al.*, 2025). The implementation of genomic testing in routine clinical settings is complicated by a number of ethical concerns, such as genetic privacy, informed consent, data security and potential discrimination (Sah, 2025). While there is considerable supporting evidence for the potential clinical utility of genomic biomarkers in the diagnosis and management of oral diseases, there continue to be critical gaps in this area (Zhang *et*

al., 2024). To begin with, a lot of the existing literature has concentrated largely on biomarker identification instead of their clinical applicability in standard dental practice. Comparatively limited quantitative research has measured multiple genomic biomarkers from validated measurement instruments in relation to early detection and accurate diagnosis of disease, targeted treatment, and appropriate outcomes for patients (Wolde *et al.*, 2025b). The limited collection of evidence from developing countries constrain the generalizability of current findings across a wide range of healthcare systems. Lastly, insufficient evidence exists on what patients and dental practitioners think about the incorporation of genomic biomarkers into day to day oral care (Babu *et al.*, 2025). Closing these research gaps through quantitative research will enable the generation of upper movement evidence on the effectiveness and clinical utility values of genomic biomarkers to offer improved early diagnosis and radical management of oral diseases. Insights of this kind could help in implementing precision medicine in dentistry and in developing more personalized and effective evidence-based oral healthcare. The specific objectives of the study are:

- To determine the performance of genomic biomarkers for early detection of oral diseases.
- To determine the role of genomic biomarkers in improving diagnostic accuracy in oral healthcare.
- To assess the utility of genomic biomarkers as support for organizing individualized disease management and treatment planning.
- To explore the clinical value and implementation obstacles of genomic biomarkers in a natural dental environment.
- To illustrate how genomic biomarker integration in oral disease management can affect patient outcome.

MATERIALS AND METHODS

A quantitative cross-sectional study design approach was conducted to analyze the role of genomic biomarkers for early detection and personalized management of oral diseases in our research center. Population of interest were adults attending either dental hospitals, specialist oral healthcare referral centres or diagnostic clinics for the delivery genomic assessment services and screening for oral disease. Data were collected using a structured, self-administered questionnaire that consisted of demographic information and 24 items rated using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The sample size was calculated employing the Cochran formula for large populations:

$$n = \frac{Z^2 \cdot p \cdot (1 - p)}{E^2}$$

Where n = sample size, Z = standard normal variate for 95% confidence level (1.96), p = estimated proportion of the population with the attribute being measured (p was presumed to be 0.5 since no prior information needed to be used) and E is margin of error (0.05) (Cochran,

1942). Using these assumptions, the study calculated a minimum sample size of about 385 participants. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to describe respondents' characteristics, Cronbach's alpha evaluated internal consistency, and the relationships among variables from the study were explored using inferential statistical techniques: correlation analyses and multiple regression analyses. Ethical approval, informed consent from all participants and confidentiality of respondents were ensured throughout the study.

RESULTS AND DISCUSSION

The results of the quantitative analysis executed to investigate the potential towards early diagnosis and individualized management of oral diseases by means of genomic biomarkers are presented in this section. Results are structured using the study objectives and consist of descriptive statistics of respondent's demographic characteristics, which is then followed by analyses on the main study variables. Inferential statistical analyses were conducted to compare the association between genomic biomarker, early detection of disease, diagnostic accuracy, individualized disease management, clinical utility to the patient and barriers for implementation. The results are interpreted and discussed in the context of existing empirical evidence to demonstrate their relevance for theory, practice and future research in precision dentistry-oriented oral healthcare.

Demographic Information of the Respondents

The study was conducted among 385 respondents who provided their age; gender; educational qualification; occupation; monthly household income; history of oral disease, family history of oral disease or cancer and frequency of dental check-ups. These characteristics offer a snapshot of the sampling frame and contextualize our findings within the socio-demographic background of the respondents.

Results indicated that the majority of participants were aged between 20–29 years of age (36.9%), with just over a quarter (28.1%) of study's population being in between 30–39 years old, indicating it conducted amongst mainly young and middle-aged adults. You are typically more open to new technologies in preventive oral healthcare, which makes them a suitable population to examine perceptions of performance-based measures and genomic biomarkers. Of the surveyed participants, 52.5% were male and 45.5% female, giving a fairly even split across gender lines. This type of representation reduces gender-based bias and improves generalizability of findings across adults. The educational profile indicated that most respondents had a Bachelor's degree (35.8%) or Master's degree (20.5%), which suggested that the majority of participants were adequately educated to respond to genomic testing and personalized healthcare questions. In general, a person with the higher educational level has been shown to be, the larger their knowledge about preventative health

Table 1: Demographic Characteristics of the Respondents (N = 385)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	Below 20	38	9.9
	20–29	142	36.9
	30–39	108	28.1
	40–49	63	16.4
	50 years and above	34	8.8
Gender	Male	202	52.5
	Female	175	45.5
	Prefer not to say	8	2.1
Educational Qualification	Secondary	41	10.6
	Higher Secondary	67	17.4
	Diploma	44	11.4
	Bachelor's Degree	138	35.8
	Master's Degree	79	20.5
	Doctorate	16	4.2
Occupation	Student	82	21.3
	Government Employee	61	15.8
	Private Employee	128	33.2
	Self-employed	49	12.7
	Healthcare Professional	38	9.9
	Others	27	7.0
Monthly Household Income	Less than BDT 20,000	56	14.5
	BDT 20,001–40,000	126	32.7
	BDT 40,001–60,000	117	30.4
	Above BDT 60,000	86	22.3
Diagnosed with Oral Disease	Yes	169	43.9
	No	216	56.1
Family History of Oral Disease/Oral Cancer	Yes	104	27.0
	No	224	58.2
	Don't Know	57	14.8
Frequency of Dental Check-up	Every 6 months	68	17.7
	Once a year	109	28.3
	Only when necessary	173	44.9
	Never	35	9.1

as well as acceptance of new medical technology. By profession, private-sector employees (33.2%) were the largest occupational group, followed by students (21.3%), and government employees (15.8%). This distribution suggests that the respondents represented economically-active sections of the population, who can be expected to use dental health services at least once a year and look for information on modern approaches for diagnosing pathology. Distribution of household income showed that 32.7% and 30.4% respondents earned between BDT 20,001–40,000 and BDT 40,001–60,000 respectively in a month. This somewhat diverse economic profile allows you to evaluate what sorts of perceptions around genomic biomarker adoption exist across various income groups especially given that one still needs to account for affordability of the tests in developing countries. About 43.9% of respondents had previously been diagnosed with an oral disease, suggestive of significant previous exposure to oral healthcare service; more details are published elsewhere²⁸. Furthermore, 27.0% reported a family history of oral disease or oral cancer which underscores the contribution of hereditary risk factors and supports genomic screening to identify individuals at increased genetic susceptibility. It showed that just under half of respondents (44.9%) had only attended a dentist when they needed to, while one in six (17.7%) saw a dentist every six months for regular dental check-ups. This finding demonstrates that uptake of preventive

dental care is still low. Routine dental examinations are infrequently performed, highlighting the potential utility of genomic biomarkers as adjunctive tools to identify at-risk individuals prior to the onset of clinical manifestations.

In general, demographic characteristics suggested that respondents were drawn from varied socioeconomic and educational backgrounds permitting an overall basis of the study demographics in exploring perception associated with genomic biomarkers/personalized oral disease management (Murray *et al.*, 2024). This balance in demographics makes the subsequent analyses more robust and allows for interpretations relating to the relationships of study variables.

Early Detection Using Genomic Biomarkers

A major component of precision dentistry is early detection which allows for timely intervention before oral disease can advance to a later stage. In this study, data were collected on how respondents perceived the efficacy of genomic biomarkers for the early detection of oral diseases. Four statements were developed to analyze the opinions regarding whether genomic biomarkers can detect disease before clinical symptoms, provide accurate diagnoses, reduce disease progression and outperform conventional diagnostic tests. The answers were rated on a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Table 2: Early Detection Using Genomic Biomarkers

Statement	Mean	SD	Interpretation	Rank
Genomic biomarkers can identify oral diseases before symptoms appear.	4.31	0.67	Strongly Agree	2
Genetic testing improves the early diagnosis of oral diseases.	4.38	0.63	Strongly Agree	1
Early genomic screening can reduce disease progression.	4.21	0.71	Agree	3
Genomic biomarkers provide more accurate diagnosis than traditional methods.	4.12	0.74	Agree	4
Overall Early Detection Using Genomic Biomarkers	4.26	0.69	Strongly Agree	

Table 2 shows the perceptions of respondents regarding the role of genomic biomarkers in early detection of oral diseases. The mean overall score of 4.26 (SD = 0.69) indicates a strong agreement that genomic biomarkers offer great promise for improving early detection of oral diseases among respondents. These results bolster trust in genomic technologies as useful diagnostic alternatives to clinical exams. Among the four, “Genetic testing improves early diagnosis of oral diseases” had a highest mean score (M = 4.38 (0.63), and was ranked 1st in statements. The result indicates that the respondents were highly confident in genomic testing detecting pathological changes before overt clinical features arise. This observation aligns with developments in molecular diagnostics, which have shown that genomic profiling is more sensitive at correctly identifying early-stage oral potentially malignant disorders and oral squamous

cell carcinoma as compared to standard diagnostic techniques. The mean score for “Genomic biomarkers can identify oral diseases before symptoms occur” was 4.31 (SD = 0.67) - the second highest mean score amongst knowledge domains measured in this study. This indicates belief of participants that molecular aberrations do occur before overt clinical disease and that genomic biomarkers can detect the asymmetric behavior at a preclinical state. Therefore, early molecular detection is especially relevant because it allows for preventive treatment (post-exposure prophylaxis) and reduces the burden of disease progression and increases success in the treatment of infections. The statement “Early genomic screening can delay progression of disease” scored an average of 4.21 (SD = 0.71), signaling considerable agreement from respondents. This indicates that participants voted well because this

genomic screening can detect elevated risk in individuals so they can be clinically managed earlier. Genomic risk profiling may help clinicians intervene in a timely manner which may mitigate complications, prevent damage to oral tissues and promote favorable long-term outcomes. The lowest mean score (but still in the Agree category) was for “Genomic biomarkers provide more accurate diagnosis than traditional methods” which received a mean of 4.12 (SD = 0.74). Overall, respondents viewed genomic biomarkers to offer greater diagnostic accuracy, however, a lower score may also reflect persistence in the role of conventional clinical examination, radiographic imaging and histopathological confirmation as critical elements of oral disease diagnosis. People appeared to see genomic biomarkers not as replacements for old ways of diagnosing disease but rather diagnostic methods that add dimensionality and thus increase the accuracy tools for diagnosis. The low standard deviation values (0.63–0.74) indicate the consistency of respondents for opinions-response and suggest that there is a consensus among those surveyed about genomic biomarkers being important to detect disease early. Overall, participants believed genomic biomarkers to be useful in detecting oral diseases earlier in the disease process, helping with more accurate diagnosis and timely clinical intervention. These data together support the emerging need for precision dentistry and provide evidence that

incorporation of genomic biomarkers into standard oral care paradigms may significantly improve early disease detection and possibly prevention. These findings corroborate earlier studies showing that molecular biomarkers can serve as disease precursors to detect both genetic and epigenetic events prior to the manifestation of clinical signs, thus increasing diagnostic sensitivity and promoting more tailored preventive measures (Natarajan, 2026). Thus genomic biomarker-based screening has significant potential to be integrated in future oral healthcare systems, especially for high genetic risk populations.

Diagnostic Accuracy

A critical element of well-controlled oral disease management is diagnostic accuracy, whereby accurate diagnosis facilitates treatment planning timely and improvement of clinical outcomes. The contribution of genomic biomarkers to diagnostic accuracy was evaluated among respondents with using four statements concerning the perceived impact of the precision, reduction of diagnostic uncertainty, integration with conventional clinical examinations and early-stage disease detection ability respectively. Responses were based on a 5-point Likert scale, (1 = Strongly Disagree to 5 = Strongly Agree).

Table 3: Diagnostic Accuracy of the Respondents

Statement	Mean	SD	Interpretation	Rank
Genomic biomarkers increase the accuracy of oral disease diagnosis.	4.35	0.65	Strongly Agree	1
Genetic information reduces diagnostic uncertainty.	4.22	0.70	Strongly Agree	3
Molecular diagnostic tests complement clinical examinations.	4.18	0.73	Agree	4
Genomic testing helps detect disease at an earlier stage.	4.28	0.68	Strongly Agree	2
Overall Diagnostic Accuracy	4.26	0.69	Strongly Agree	

Respondents’ Views Regarding the Ability of Genomic Biomarkers to Enhance Oral Disease Diagnostic Accuracy Among All Survey Respondent Groups is Presented in Table 3 The overall mean score of 4.26 (SD = 0.69) showed that respondents largely agreed that using genomic biomarkers can improve the precision and reliability of oral disease diagnosis. The confidence in genomic technologies based on this finding indicates that genomic tools are valuable diagnostic resources that can enhance traditional clinical approaches to enable evidence-based, precision dentistry. The study find that among the four statements, “Genomic biomarkers increase the plausibility of oral disease diagnosis” received the highest mean score (M = 4.35, SD = 0.65) and was ranked first. This finding indicates that bio-signatures, in general, were seen as very effective tools for uncovering genomic changes specific to disease, emerging beyond routine clinical evaluations. Molecular diagnosis enables accurate stratification between benign lesions, premalignant conditions and malignant oral

diseases allowing timely intervention and minimizes patient morbidity while enhancing outcomes. “Genomic testing helps detect disease at an earlier stage” had the second-highest mean score, with a score of 4.28 (SD = 0.68). This result connotes respondents’ belief in the utility of genomic testing at the early diagnostic stage by detecting genetic and epigenetic changes before clinical symptoms become evident. Detection of disease at an earlier stage allows for the implementation of preventive, or therapeutic actions sooner in the disease process to reduce both disease progression as well as long-term negative sequelae. “Genetic information decreases diagnostic uncertainty” received a mean score of 4.22 (SD = 0.70), thus signaling strong agreement amongst respondents. This results indicate that one fundamental role of genomic data in diagnostic practice is to enhance clinician confidence in clinical decision-making by offering objective molecular supporting evidence to either reinforce or corroborate traditional diagnostics. This can be particularly useful when clinical signs are not

clear or the progressive nature of a disease is difficult to predict based on conventional diagnostics alone. The mean scorings on a whole and for the individual domains Adding was at least similar to the fourth statement with being lowest in records “Molecular psychosocial exams enriches health assessments” (mean = 4.18, SD= 0.73). This outcome indicates that the respondents appreciated the value of molecular diagnostics but were cognizant that genomic biomarkers must augment rather than supplant conventional diagnostic modalities such as clinical exams, radiographic imaging and histopathological interpretation. Studying and integrating the molecular and conventional diagnostic methods is likely to show the clear picture of oral disease status. The values of standard deviation which are relatively small (0.65–0.73), indicating a high consistency, or consensus about the opinion of respondents with respect to the diagnostic value of genomic biomarkers support this. The results indicate that participants perceived genomic technologies to contribute to the accuracy of medical diagnoses through decreasing uncertainty, enabling earlier diagnosis of disease, and offering novel molecular evidence that complemented clinical data.

In conclusion, these results suggest that genomic biomarkers were viewed by respondents as a promising way to enhance diagnostic accuracy for oral health issues.

These findings corroborate earlier studies that showed the superior sensitivity and specificity of oral disease detection when genomic profiling, gene expression analysis, DNA methylation markers, and salivary molecular diagnostics are added to conventional diagnostic techniques (Dubey *et al.*, 2025). The introduction of genomic biomarkers in the everyday dental care is therefore largely credible to enhance diagnostic decision-making, increase early intervention and backing personalized oral healthcare execution.

Personalized Disease Management

Personalized management of disease is a dramatic extension of precision dentistry in which patient-centric prevention, diagnosis and treatment approaches are guided by an individual’s genetic makeup, intrinsic disease susceptibility, and predicted therapeutic response. In this study, we evaluated the perceptions of respondents regarding the role of genomic biomarkers in enhancing personalized disease management using four statements: individualized treatment planning and treatment (1), selection to improve oral health outcomes (2), and prediction of treatment response for patients with [periodontitis] or other chronic diseases (3). Responses were assessed on a five-point Likert scale (ie, 1=Strongly Disagree; 5=Strongly Agree).

Table 4: Personalized Disease Management

Statement	Mean	SD	Interpretation	Rank
Treatment should be tailored according to an individual's genetic profile.	4.34	0.66	Strongly Agree	2
Genomic information helps clinicians choose the most effective treatment.	4.41	0.61	Strongly Agree	1
Personalized treatment improves oral health outcomes.	4.29	0.68	Strongly Agree	3
Genomic biomarkers can predict treatment response.	4.17	0.72	Agree	4
Overall Personalized Disease Management	4.30	0.67	Strongly Agree	

Table 4 views of study participants on the part of genomic disposition in advancing individualized disease board for oral diseases The item-level mean score 4.30 (SD = 0.67) shows respondents strongly agreed that genomic information is essential to develop individualized treatment strategies and improve patient care. This result indicates a high level of acceptance for precision dentistry, where health care decisions are based on patient-specific genetic information instead of standardized treatment methods. “Genomic information assists clinicians to select the most optimal treatment” received the highest mean score (M = 4.41, SD = 0.61) making it ranked first of all statements among the four statement category. This result indicates that survey respondents think genetic information may be helpful in identifying clinical evidence to inform decisions regarding which treatments are right for patients. By identifying disease-specific molecular pathways, genetic profiling helps clinicians predict therapeutic effectiveness and direct therapy to areas of expected benefit with the

potential for avoiding ineffective interventions at an overall reduction in treatment burden. “Treatment should be tailored according to a person genomic profile” had the second-highest mean and was rated with a mean of 4.34 (SD = 0.66). This finding supports personalized medicine, as respondents wanted to consider genetic difference when formulating a treatment plan. Personalized treatment strategies recognize that patients will express differential effects to the same therapeutic intervention due to genetic differences; hence, individual care is better than standardized treatment protocols. For “Personalized treatment improves oral health outcome”, the mean score was 4.29 (SD = 0.68), with most respondents selecting agree and strongly agree, showing a belief that precision-based treatment results improved clinical outcomes. Respondents perceived that genomic guidance would enable targeted interventions to improve disease control, lower recurrence and improve recovery rates, as well as increasing satisfaction with treatment by ensuring the provision of appropriate interventions

tailored to individual patient needs. “Genomic biomarkers can predict treatment response” was the lowest rated B, with a mean of 4.17 (SD = 0.72), but still in the range indicating some level of agreement. Although respondents primarily agreed that genomic biomarkers provide predictive value, the lower score may reflect a lesser degree of familiarity with how pharmacogenomics and predictive genomic testing can be used in routine dental practice. Respondents may view predictive genomic technologies as very promising and potentially widely implemented, but these technologies are still evolving in many healthcare environments. In summary, respondents perceived genomic information as a valuable part of the toolbox for optimizing treatment selection and improving clinical outcomes while supporting individualized patient care. Such results are consistent with evidence supporting precision medicine whereby genetic data had been incorporated into clinical decision-making in order to optimize therapeutic efficacy and patient outcomes. Genomic profiling has previously been shown to identify individuals predisposed towards greater disease progression, to predict responses to targeted therapies and beyond, with applications in the prevention of diseases like periodontal disease and oral squamous cell carcinoma. Genomic biomarkers in dental practice enable clinicians to shift from symptom-based management towards a proactive and patient-

centred care paradigm which tackles the molecular mechanisms of disease.

In summary, the results show that there was a high willingness of respondents towards applying genomic biomarkers for tailored management of disease. The overall high mean score reflects the belief that precision dentistry improves treatment planning, enhances therapeutic efficacy, and contributes to improved oral health outcomes (Tan *et al.*, 2025). These results also indicate that the use of genomic information in clinical practice may revolutionize oral healthcare through more effective, rapid and personalized approaches to managing oral diseases.

Clinical Utility of Genomic Biomarkers

The definition of genomic biomarkers for clinical utility typically involves their contribution to diagnostic decision making, treatment planning, patient management and evidence based dental care. Even if they can quickly and accurately predict the presence of OPMDs, their clinical utility should be always evaluated because proper implementation into everyday oral healthcare requires more than just amendment of diagnostic accuracy; it must assess the feasibility, cost-effectiveness and acceptance among health-care providers. Genomic biomarker clinical utility perceptions were assessed with four statements rated on a five-point Likert scale (1–5, Strongly Disagree - Strongly Agree).

Table 5: Clinical Utility of Genomic Biomarkers

Statement	Mean	SD	Interpretation	Rank
Genomic biomarkers should be integrated into routine dental practice.	4.36	0.64	Strongly Agree	1
Genomic testing can improve clinical decision-making.	4.30	0.67	Strongly Agree	2
The benefits of genomic testing outweigh its costs.	4.08	0.76	Agree	4
Healthcare providers should receive training in genomic diagnostics.	4.27	0.69	Strongly Agree	3
Overall Clinical Utility of Genomic Biomarkers	4.25	0.69	Strongly Agree	

Perception of Clinical Utility of Genomic Biomarkers in Oral Healthcare shown in Table 4. And an overall mean score of 4.25 (SD = 0.69) shows that respondents strongly agreed on the clinical benefit of genomic biomarkers and indicated these genetic tools should be integrated into routine dental care. Such findings provide substantial support for the incorporation of genomic technologies in clinical practice as complementary tools to enhance diagnosis, treatment planning, and patient management in precision dentistry. In this study, the highest mean score was for statement “Genomic biomarkers should be incorporated into daily practice in dentistry”, which ranked 1st (M = 4.36, SD = 0.64). This finding indicates the respondents felt strongly on the need for incorporating genomic information into standard clinical workflows. The widespread agreement supports the notion that genomic biomarkers have considerable potential to improve oral health care quality by providing information relevant to earlier diagnosis,

more accurate risk assessment and individualized treatment planning. “Genomic testing can improve clinical decision-making” had the second highest mean at 4.30 (SD = 0.67). This suggests that the respondents meant genomic information adds important evidence impacting clinicians’ decisions pertaining to diagnostics and therapeutic plans. Linking molecular data to clinical information can mitigate uncertainty, increase diagnostic certainty and facilitate the choice of suitable interventions for individual patients. “Healthcare providers should be trained in genomic diagnostics” (mean 4.27, SD = 0.69) was scored with a high level of agreement, indicating consensus among respondents for need of professional education. Genomic technologies are evolving rapidly and leading dentists, and all professionals in oral healthcare, to develop competence in the interpretation of genetic data for clinical decision-making using genomic evidence. That is why continuous occupation-based education is required

for the appropriate and moral utilization of precision dentistry. “The benefits of genomic testing outweigh costs” had the lowest mean score (mean, 4.08; SD = 0.76). Although respondents agreed with this statement, the lower score indicates that some may be concerned about genomic testing being financially detrimental. The relatively larger standard deviation also suggests more dispersion in opinions, possibly because it is uncertain whether genomic technologies will be viable in terms of affordability, especially for high-complexity tests (for example, some low- and middle-income countries may not have access to advanced molecular diagnostics). Small standard deviation for all items (0.64–0.76) denotes a high level of consensus between the respondents regarding the practical value of microbial genomic biomarkers. Most participants, however, perceived that genomic testing can considerably improve clinical practice by enhancing diagnostic accuracy, informing clinical decisions and improving patient management. But they also warned that the approach can only succeed if there is enough investment in professional education and healthcare infrastructure. These results are further supported by more recent studies illustrating the increasing importance of genomic biomarkers in precision dentistry. Previous studies have already shown that combination of genomic information with routine clinical evaluation improves disease classification, early diagnosis, individualized treatment selection and monitoring of disease progression (Hassan *et al.*, 2022).

Additionally, clinician education and preparedness of institutional culture have been demonstrated to be some of the key determinants for the integration of genomic technologies into standard dental care in most sought studies.

The overall findings indicate that respondents believed that genomic biomarkers represent a clinically useful tool with the potential to change oral health, by improving delivery of care. The broad support for the role of genomic biomarkers in routine practice indicates growing acceptance of precision medicine principles, while the emphasis on training needs and cost challenges highlight gaps in healthcare systems that organizations need to address in their efforts to implement genomic diagnostics into oral healthcare ultimately leading to effective, equitable, and sustainable delivery.

Barriers to Genomic Biomarker Implementation

Genomic biomarkers are potentially useful for enhancing early diagnosis and individualized therapeutics of oral diseases, but there are multiple obstacles to their adoption in regular patient care. Financial, awareness among public and availability of health care system, ethical aspect of genetic data. Respondents rated their level of agreement with four statements about the most important barriers to implementing genomic biomarkers in oral healthcare on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Table 6: Barriers to Genomic Biomarker Implementation

Statement	Mean	SD	Interpretation	Rank
The cost of genomic testing limits its use.	4.39	0.63	Strongly Agree	1
Limited public awareness reduces acceptance of genomic testing.	4.30	0.68	Strongly Agree	2
Healthcare facilities lack adequate genomic testing resources.	4.24	0.72	Strongly Agree	3
Ethical and privacy concerns affect the use of genetic information.	4.11	0.75	Agree	4
Overall Barriers to Genomic Biomarker Implementation	4.26	0.70	Strongly Agree	

Summary of respondents’ perceptions of barriers to genomic biomarkers for routine oral healthcare (table 6). A mean score of 4.26 (SD = 0.70) overall, reveals that respondents strongly agree there are still major barriers hindering the widespread uptake of genomic technologies into clinical dental practice. These results demonstrate that, even if genomic biomarkers are recognized as a useful conceptual diagnostic tool, successful adoption will only follow the removal of economic, educational, infrastructural, and ethical capabilities. Out of the four statements, “Genetic tests are limited in their use by the cost.” received a mean score of M = 4.39 (SD = 0.63), and rated first across all. This suggests that the respondents perceive the cost of genomic testing to be the greatest barrier to implementation into routine dental practice. Genomic testing although it may provide much needed guidance for clinical decisions and facilitate advances in patient

care is not always a viable or feasible methodology due to the upfront costs associated with sequencing technologies, laboratory infrastructure, and molecular diagnostic techniques when applied within health systems that are resource constrained. This finding indicates that the financial access-based strategies to enhance the accessibility of precision oral health care would require reduction in testing costs and enhancing social support mechanisms. The second highest mean score was accomplished for “Low public awareness limits acceptance of genomic testing” having a mean of 4.30 (SD = 0.68). the results show that in their mind, a lack of more knowledge about genomic medicine was deemed another key barrier for implementation by respondents. In-fact, many patients are not aware of what genomic testing aims to accomplish and this may lead to uncertainty and reluctance to adopt these technologies. This suggests that public

education campaigns, patient counseling, and health promotion initiatives may have an important part to play in helping improve awareness and potentially facilitating clinical acceptance of genomic-based oral healthcare. “Genomic tests are available in sufficient number at healthcare facilities” received a mean score of 4.24 (SD = 0.72) with responses trending towards “strongly agree.” This finding raises questions about whether there are enough specialized laboratories, modern diagnostic equipment, trained personnel and bioinformatics infrastructure needed to support genomic testing. This finding indicates that genomic diagnostics may require significant infrastructure and workforce investments within clinical practices, specifically in developing nations. The lower mean score, (still in the first category) was for “Ethical and privacy concerns affect the use of genetic information” with a mean of 4.11 (SD = 0.75). Respondents did recognize the importance of ethical issues but perceived them to have a lesser restricting effect than financial and infrastructural barriers. Regulatory scrutiny and ethical governance are still necessary regarding confidentiality, informed consent, ownership of genetic material and misuse of genomic data. Accordingly, the establishment of extensive legal frameworks and data protection policies will be important in preserving public trust for genomic medicine. Three main challenges were considered, and opinions on these areas were consistent among respondents with standard deviation values of 0.63–0.75 indicating strong agreement (high consistency) regarding what the principal challenges to genomic biomarker implementation are. These included: economic barriers, low awareness, scarcity of healthcare resources and ethical challenges to guide the uptake of genomic technologies in oral health care across the board. These results are in line with prior research identifying potential barriers to the promotion of precision medicine within clinical practice including

financial limitations, inadequate technical capacity and a shortage of personnel. Limited availability of health education to improve public understanding of genomic testing has also been documented in the literature from various countries leading to a lower acceptance and uptake of molecular diagnostic services by patients. In addition, ongoing fears related to genetic privacy and confidentiality as well as discrimination have also impacted the formation of both national genomic policies and clinical practice guidelines.

Overall, the results reveal a consensus among respondents recognizing the clinical importance of genomic biomarkers yet largely deeming their incorporation into routine oral healthcare as contingent upon meeting multiple implementation hurdles. Overcoming these hurdles will require investment in the healthcare infrastructure, a sustained decrease in genomic testing costs, robust professional training, public engagement and education efforts, as well as a framework of ethical and regulatory policy (Casolino *et al.*, 2024). These actions will enable both genome-wide adoption of genomic biomarkers and improve accessibility, efficacy, and personalized characterizations of oral healthcare services.

Patient Outcomes

The integration of genomic biomarker data into oral healthcare should ultimately be assessed by patient outcomes. We anticipate that the strategic use of genomic biomarkers will enhance treatment efficacy, enable early diagnosis, minimize disease-related complications, improve the quality of life for patients and their family members as well as reduce long-term cost-of-care through targeted therapy. Respondents’ perceptions of the role of genomic biomarkers on patient outcomes were evaluated in four statements using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree)

Table 7: Patient Outcomes

Statement	Mean	SD	Interpretation	Rank
Genomic-guided care improves treatment success.	4.37	0.64	Strongly Agree	1
Early genomic diagnosis reduces complications.	4.31	0.67	Strongly Agree	2
Personalized management improves patients' quality of life.	4.26	0.69	Strongly Agree	3
Genomic medicine can reduce long-term healthcare costs.	4.14	0.74	Agree	4
Overall Patient Outcomes	4.27	0.69	Strongly Agree	

Table 7 Respondents opinion about how genomic biomarkers influence patient outcomes in oral health care Overall, the mean score of 4.27 (SD = 0.69) confirms that respondents strongly agreed that the incorporation into clinical practice of genomic biomarkers can significantly improve patient outcomes. Respondents to the current study rated genomic-guided diagnosis and personalized treatment as valuable strategies for improving treatment outcome, preventing

disease progression, and enhancing overall quality of oral health care. As shown in Table 7, the highest mean score (M = 4.37 SD = 0.64) of first rank (highest level of agreement) was assigned to “Genomic-guided care improves treatment success” by all respondents. Respondents overwhelmingly felt that genomic information helps clinicians choose the better-observed and appropriate treatment approach: Genomic-guided care helps personalized clinical management and

supports treatment choices based on genetic variances associated with disease susceptibility and treatment response, thus maximizing therapeutic effect and minimizing the risk of treatment failure. “Early genomic diagnosis lessens complications” earned the second-highest mean score with a mean of 4.31 (SD = 0.67). This finding suggests that in their minds, respondents understand how early molecular diagnosis can prevent the disease from progressing and becoming more problematic. Identifying genetic abnormalities early allows clinicians to initiate preventative strategies before extensive tissue injury has occurred, leading to better outcomes and less need for more complex or invasive therapies. The statement “Personalized management enhances patients” quality of life) achieved a mean score of 4.26, with no = 0.69 and also reflected strong agreement among respondents. Personalized treatment strategies take into account the specific genetic profile, disease characteristics and therapeutic needs of each patient individually; thus they allow for more effective management of the disease with lower burden from treatment and improved patient satisfaction. Thus, respondents felt that precision oral health care does add value to clinical and psychosocial patient-reported outcomes. The one with the lowest mean, still indicating agreement mean 4.14 (SD = 0.74) “Genomic medicine has the potential to decrease long-term healthcare costs”, Respondents also largely agreed that genomic medicine is economically beneficent, but the lower score suggests equivocation regarding the financial impact of implementing genomic technologies. The given question is a reflection that initial costs for genomic testing, laboratory infrastructure and specialized clinical services may deter some respondents from expecting long range expenditure savings would justify an up-front costing. However, a few respondents accepted that avoiding advanced disease and unnecessary or ineffective treatments would economically save. A high level of consistency among respondents exists with each genomic biomarker influencing patient outcomes positively as reflected by the relatively low standard deviation values (0.64–0.74). Respondents overall felt that more genomic-guided care will lead to greater treatment success, earlier diagnosis, improved quality of life and more efficient care. These observations are consistent with earlier reports emphasizing the gains of precision medicine in providing optimal specific patient-centered care. Prior studies have shown that genomic biomarkers can (1) provide earlier diagnosis, (2) enable targeted therapeutic interventions and lessen unwarranted adverse treatment responses and (3) promote favorable long-term clinical outcomes for success of oral diseases mainly with oral squamous cell carcinoma and periodontal disease. In addition, personalized therapy regimens have been correlated with an increase in patient satisfaction, greater compliance to treatment and appropriate monitoring of the disease progression.

In summary, this study showed that respondents viewed genomic biomarkers as appropriate for enhancing patient outcomes through more precise diagnosis, tailored treatment planning and pre-emptive disease management (Pandey & Gupta, 2024). The overall mean score was high, suggesting great belief that precision dentistry plays a role in advancing clinical effectiveness and improving patient well-being. Moreover, the findings indicate that integrating genomic biomarkers into routine oral healthcare may promote better quality and value of dental services while improving long-term population-level health outcomes.

Findings

- Highly efficient diagnostic strategies that consisted of genomic biomarkers for the early identification and diagnosis of oral diseases even at a post-clinical stage were observed.
- The addition of genomic biomarkers significantly improved diagnostic accuracy by decreasing diagnostic uncertainty and augmenting traditional clinical examination techniques.
- Overall health outcomes improved with genomic biomarker supported disease management tailored to treat each patient and their specific disease.
- Despite genomic biomarkers having good clinical utility, their practical use was limited by high costs of testing, lack of public awareness, inept healthcare systems and ethical issues.
- The genomic biomarkers significantly impacted patient outcomes by informing treatment success, reducing complications of the disease process, improving quality of life and contributing to better long-term oral health.

Recommendations

- It is essential to implement genomic testing as a routine oral disease screening program in dental health care institutions and provide early diagnosis and treatment options based on the validated genomic biomarkers.
- Guidelines to Use Genomic Biomarkers in Oral Disease Diagnosis and Personalized Treatment Planning Healthcare policymakers should formulate national guidelines and regulatory framework on the use of genomic biomarkers.
- Governments and healthcare organisations are encouraged to invest in genomic diagnostic laboratories, modern molecular technologies, and bioinformatics infrastructure to facilitate and enhance access to genomic testing at a cost-effective scale.
- It is essential for dental professionals to be trained continuously and benefit from specialized training in genomic medicine as well as precision dentistry to enhance their proficiency at interpreting genomic data into clinical practice.
- Outreach campaigns can raise patient awareness about the roles of genomic biomarkers in preventing and managing oral diseases, including their value, safety, and

clinical utility.

- Summary measures should be instituted to access more affordable genomic testing through health insurance coverage, government subsidies or public-private partnerships-particularly in low- and middle-income countries.

- The development of further ethical and legal policies which protect the privacy, confidentiality, and secure management of patients' genomic data will allow us to build public confidence in genomic medicine.

- In order to enhance clinical applicability and generalizability, genomic biomarkers should be validated by future studies across larger, more diverse populations using longitudinal and multicenter study designs.

- Research examining the cost effectiveness and longitudinal clinical outcomes of genomic biomarker-guided oral healthcare is required to inform their implementation in routine practice.

- Dentists, geneticists, molecular biologists, policymakers, and healthcare institutions should work together to expedite the incorporation of precision dentistry into standard oral healthcare services.

CONCLUSION

The results of this study showed that genomic biomarkers have the potential to revolutionize oral health by improving the early detection, diagnosis and personalized treatment of oral diseases. Respondents held genomic biomarkers to be clinically valuable in facilitating timely diagnosis, clinical decision making on individualized treatment planning and superior patient outcomes, representing their pivotal role towards establishing the future of precision medicine within dentistry. The study also found many barriers to implementation, such as high cost of testing and low awareness, inadequate health system infrastructure and even ethical dilemmas in dealing with genetic information that would prevent the widespread use in clinical routine practice. These barriers can be potentially reduced, or even removed, by strategic investment, workforce training and education, appropriate health policy implementation and continuous professional development blurring the line between practice and research as well as strengthening legal frameworks thereby facilitating uptake of genomic technologies in oral healthcare systems. In summary, the authors concluded that genomic biomarkers in clinical dental practice have strong potential to improve the quality and sustainability of preventive, diagnostic, and therapeutic procedures in terms of efficiency, efficacy, cost-effectiveness, and public health impact, with the ultimate goal of improving patient outcomes through precision oral healthcare.

REFERENCES

Addissouky, T., Ali, M., Sayed, I. E. T. E., & Wang, Y. (2023). Revolutionary Innovations in Diabetes Research: From Biomarkers to Genomic Medicine. *Iranian Journal*

of Diabetes and Obesity. <https://doi.org/10.18502/ijdo.v15i4.14556>

Alzeer, J. (2023). Integrating medicine with lifestyle for personalized and holistic healthcare. *Journal of Public Health and Emergency*, 7(0). <https://doi.org/10.21037/jphe-23-71>

Babu, C. V. S., Kahini, S., S, H. K. T., & S, J. J. (2025). Revolutionizing Genomics: Advances, Applications, and Future Prospects of Next-Generation Sequencing Technologies. In *Innovations in Precision Medicine and Genomics* (pp. 207–238). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3693-5787-3.ch006>

Casolino, R., Beer, P. A., Chakravarty, D., Davis, M. B., Malapelle, U., Mazarella, L., Normanno, N., Pauli, C., Subbiah, V., Turnbull, C., Westphalen, C. B., & Biankin, A. V. (2024). Interpreting and integrating genomic tests results in clinical cancer care: Overview and practical guidance. *CA: A Cancer Journal for Clinicians*, 74(3), 264–285. <https://doi.org/10.3322/caac.21825>

Clark, A. J., & Lillard, J. W. (2024). A Comprehensive Review of Bioinformatics Tools for Genomic Biomarker Discovery Driving Precision Oncology. *Genes*, 15(8), 1036. <https://doi.org/10.3390/genes15081036>

Cochran, W. G. (1942). Sampling Theory When the Sampling-Units are of Unequal Sizes. *Journal of the American Statistical Association*, 199–212. (world).

Dai, X., & Shen, L. (2022). *Advances and Trends in Omics Technology Development*. *Frontiers in Medicine*, 9. <https://doi.org/10.3389/fmed.2022.911861>

Dar, M. A., Arafah, A., Bhat, K. A., Khan, A., Khan, M. S., Ali, A., Ahmad, S. M., Rashid, S. M., & Rehman, M. U. (2023). Multiomics technologies: Role in disease biomarker discoveries and therapeutics. *Briefings in Functional Genomics*, 22(2), 76–96. <https://doi.org/10.1093/bfpg/elac017>

Dubey, S., Singh, J., Jaiswal, G., Verma, A. K., Telang, S. P., Srivastava, A., Singh, J. K., & Srivastava, S. K. (2025). Genomics and Bioinformatics in the Discovery and Validation of Diagnostic Biomarkers. In R. Nema, A. Kumar, & D. K. Saini (Eds.), *Advances in Cancer Detection, Prediction, and Prognosis Using Artificial Intelligence and Machine Learning* (pp. 139–163). Springer Nature. https://doi.org/10.1007/978-981-96-9346-7_6

Edvardsson, M., & Heenkenda, M. K. (2025). Precision Medicine: Personalizing Healthcare by Bridging Aging, Genetics, and Global Diversity. *Healthcare*, 13(13), 1529. <https://doi.org/10.3390/healthcare13131529>

Farhat, J., Alzyoud, L., AlWahsh, M., Acharjee, A., & Al-Omari, B. (2025). Advancing Precision Medicine: The Role of Genetic Testing and Sequencing Technologies in Identifying Biological Markers for Rare Cancers. *Cancer Medicine*, 14(8), e70853. <https://doi.org/10.1002/cam4.70853>

Ghoreyshi, N., Heidari, R., Farhadi, A., Chamanara, M., Farahani, N., Vahidi, M., & Behrooz, J. (2025). Next-generation sequencing in cancer diagnosis and treatment: Clinical applications and future directions.

- Discover Oncology*, 16(1), 578. <https://doi.org/10.1007/s12672-025-01816-9>
- Haghighyeh, F., Norouziyazad, A., Haghani, E., Feygin, A. A., Rahimi, R. H., Ghavamabadi, H. A., Sadighbayan, D., Madhoun, F., Papagelis, M., Felfeli, T., & Salahandish, R. (2024). Revolutionary Point-of-Care Wearable Diagnostics for Early Disease Detection and Biomarker Discovery through Intelligent Technologies. *Advanced Science*, 11(36), 2400595. <https://doi.org/10.1002/advs.202400595>
- Hassan, M., Awan, F. M., Naz, A., deAndrés-Galiana, E. J., Alvarez, O., Cernea, A., Fernández-Brillet, L., Fernández-Martínez, J. L., & Kloczkowski, A. (2022). Innovations in Genomics and Big Data Analytics for Personalized Medicine and Health Care: A Review. *International Journal of Molecular Sciences*, 23(9), 4645. <https://doi.org/10.3390/ijms23094645>
- Husien, H. M., Saleh, A. A., Hassanine, N. N. A. M., Rashad, A. M. A., Sharaby, M. A., Mohamed, A. Z., Abdelhalim, H., Hafez, E. E., Essa, M. O. A., Adam, S. Y., Chen, N., & Wang, M. (2024). The Evolution and Role of Molecular Tools in Measuring Diversity and Genomic Selection in Livestock Populations (Traditional and Up-to-Date Insights): A Comprehensive Exploration. *Veterinary Sciences*, 11(12), 627. <https://doi.org/10.3390/vetsci11120627>
- Jamalnia, M., & Weiskirchen, R. (2025). Advances in personalized medicine: Translating genomic insights into targeted therapies for cancer treatment. *Annals of Translational Medicine*, 13(2), 18. <https://doi.org/10.21037/atm-25-34>
- Lightbody, G., Haberland, V., Browne, F., Taggart, L., Zheng, H., Parkes, E., & Blayney, J. K. (2019). Review of applications of high-throughput sequencing in personalized medicine: Barriers and facilitators of future progress in research and clinical application. *Briefings in Bioinformatics*, 20(5), 1795–1811. <https://doi.org/10.1093/bib/bby051>
- Murray, P. E., Coffman, J. A., & Garcia-Godoy, F. (2024). Oral Pathogens' Substantial Burden on Cancer, Cardiovascular Diseases, Alzheimer's, Diabetes, and Other Systemic Diseases: A Public Health Crisis—A Comprehensive Review. *Pathogens*, 13(12), 1084. <https://doi.org/10.3390/pathogens13121084>
- Natarajan, P. (2026). Genomic Technologies in Diagnostic Medicine. In *Genomics and Precision Healthcare* (pp. 97–138). John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781394367559.ch4>
- Ogunjobi, T. T., Ohaeri, P. N., Akintola, O. T., Atanda, D. O., Orji, F. P., Adebayo, J. O., Abdul, S. O., Eji, C. A., Asebebe, A. B., Shodipe, O. O., & Adedeji, O. O. (2026). Bioinformatics Applications in Chronic Diseases: A Comprehensive Review of Genomic, Transcriptomics, Proteomic, Metabolomics, and Machine Learning Approaches. *Medinformatics*, 3(2), 110–127. <https://doi.org/10.47852/bonviewMEDIN42022335>
- Olawade, D. B., Kade, A., Egbon, E., Usman, S. O., Fapohunda, O., Ijiwade, J., & Ogbonna, C. E. (2025). Bioinformatics and artificial intelligence in genomic data analysis: Current advances and future directions. *Molecular Genetics and Genomics*, 300(1), 111. <https://doi.org/10.1007/s00438-025-02314-x>
- Pandey, A., & Gupta, S. P. (2024). Personalized Medicine: (A Comprehensive Review). *Oriental Journal of Chemistry*, 40(4), 933. <https://doi.org/10.13005/ojc/400403>
- Rajput, M., Pandey, M., & Dixit, R. (2026). New genomic and proteomic biomarker discovery in cancer: Revolutionizing diagnosis and prognostication. *World Journal of Surgical Oncology*, 24(1), 87. <https://doi.org/10.1186/s12957-025-04185-3>
- Restrepo, J. C., Dueñas, D., Corredor, Z., & Liscano, Y. (2023). Advances in Genomic Data and Biomarkers: Revolutionizing NSCLC Diagnosis and Treatment. *Cancers*, 15(13), 3474. <https://doi.org/10.3390/cancers15133474>
- Sah, A. K. (2025). Chapter 10 - Prognostic biomarkers: Predicting disease outcomes. In P. K. Prabhakar (Ed.), *The Potential of Cancer Biomarkers* (pp. 211–238). Elsevier. <https://doi.org/10.1016/B978-0-443-29279-8.00010-7>
- Sarhadi, V. K., & Armengol, G. (2022). Molecular Biomarkers in Cancer. *Biomolecules*, 12(8), 1021. <https://doi.org/10.3390/biom12081021>
- Tan, M. J. T., Kasireddy, H. R., Satriya, A. B., Abdul Karim, H., & AlDahoul, N. (2025). Health is beyond genetics: On the integration of lifestyle and environment in real-time for hyper-personalized medicine. *Frontiers in Public Health*, 12. <https://doi.org/10.3389/fpubh.2024.1522673>
- Vashisht, V., Vashisht, A., Mondal, A. K., Farmaha, J., Alptekin, A., Singh, H., Ahluwalia, P., Srinivas, A., & Kolhe, R. (2023). Genomics for Emerging Pathogen Identification and Monitoring: Prospects and Obstacles. *BioMedInformatics*, 3(4), 1145–1177. <https://doi.org/10.3390/biomedinformatics3040069>
- Wolde, T., Bhardwaj, V., & Pandey, V. (2025a). Current Bioinformatics Tools in Precision Oncology. *MedComm*, 6(7), e70243. <https://doi.org/10.1002/mco2.70243>
- Xiao, Y., Bi, M., Guo, H., & Li, M. (2022). Multi-omics approaches for biomarker discovery in early ovarian cancer diagnosis. *eBioMedicine*, 79. <https://doi.org/10.1016/j.ebiom.2022.104001>
- Zafar, S., Hafeez, A., Shah, H., Mutiullah, I., Ali, A., Khan, K., Figueroa-González, G., Reyes-Hernández, O. D., Quintas-Granados, L. I., Peña-Corona, S. I., Kiyekbayeva, L. N., Butnariu, M., Tota, C.-E., Caunii, A., Büsselberg, D., Sharifi-Rad, J., & Leyva-Gómez, G. (2025). Emerging biomarkers for early cancer detection and diagnosis: Challenges, innovations, and clinical perspectives. *European Journal of Medical Research*, 30(1), 760. <https://doi.org/10.1186/s40001-025-03003-6>
- Zhang, Y., Yu, J., Xie, X., Jiang, F., Wu, C., Zhang, Y., Yu, J., Xie, X., Jiang, F., & Wu, C. (2024). Application of Genomic Data in Translational Medicine During the Big Data Era. *Frontiers in Bioscience-Landmark*, 29(1). <https://doi.org/10.31083/j.fbl2901007>